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GEOLOGY 8

ANCIENT WATER LEVELS
OF THE
CHAMPLAIN AND HUDSON VALLEYS

BY
JAY BACKUS WOODWORTH

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GEOLOGY 8

ANCIENT WATER LEVELS OF THE CHAMPLAIN AND HUDSON VALLEYS

PREFACE

Several years ago a preliminary study of the Hudson-Champlain valley excited my interest in the historic problems involved in its Quaternary geology. The contributions published at that time were recognized as a very imperfect presentation of the subject and the importance of more extended and detailed investigation was strongly felt. Therefore, as soon as an opportunity was afforded in the service of the State, the aid of an expert in Pleistocene geology was invoked to take up the inquiry in detail and carry it to a conclusion. We had the good fortune to secure the services of Prof. J. B. Woodworth of Harvard University and he has carried out this plan with thoroughness while Dr. G. K. Gilbert has kindly given the use of his notes, based on several seasons of work in the St Lawrence valley. The following report is, therefore, a summary of Professor Woodworth's results obtained from 1900 to 1903, prepared after extended consultation with Mr Gilbert. While much thorough work has been done, the area is so vast and the details so complex that the report can not be regarded as final, specially many details of evidence lie beyond the national boundary. It is, however, certain that many important observations have been made, the conclusions from which constitute a substantial addition to our knowledge of Pleistocene geology.

F. J. H. MERRILL

INTRODUCTION

This report relates to an area whose Pleistocene history, though among the earliest to attract attention in this country, has remained but vaguely known and has been often interpreted as supporting contradictory views. The prevalence of clays in the Hudson valley and the occurrence of terraces early led to the general conception of its having been a marine strait connecting the St Lawrence valley with the Atlantic on the south during the Champlain period of Dana's chronology, and of its elevation and denudation during the succeeding Terrace epoch of that geologist. Of late years the very considerable enlargement of our knowledge concerning the diversity of the glacial period and the recognition of the manner in which gravels, sands and clays associated with retreating ice sheets have been laid down have so far modified earlier opinions concerning the history of other fields, that the state geologist, Dr F. J. H. Merrill, decided to undertake a survey of the glacial deposits of this region for the purpose of obtaining the information which it might give. One of the most important questions which it seemed the region might be expected definitely to determine is that of the extent of the marine submergence which followed the withdrawal of the ice sheet from the Hudson and Champlain valleys; to the solution of this question the data set forth in this report are mainly contributory.

For the better understanding of the conditions of deposition of the glacial deposits the physical geography of the region anterior to the last ice advance is briefly set forth, so far as it is at present understood. To a limited extent the phenomena of the adjacent regions in New England, New Jersey and Canada have been taken into consideration where they appeared to throw light on the problems of this district.

The investigation has been carried on for the most part as a reconnaissance of varying degrees of detail with reference to the main problem in hand, points being sought for examination which promised to be of critical value. It will thus appear when the areas are mapped in detail that many interesting and perhaps important facts have not been seen. It should be stated that the

work began at the mouth of the Hudson and was carried northward. At the beginning of the work in the Hudson valley the contoured maps were relied on for obtaining the elevations of the deltas and terrace deposits; later in the Champlain valley the use of the aneroid barometer was availed of in checking data of the same sort and for getting elevations where this mapping has not yet been extended. More precise and satisfactory methods of measurement would have more than doubled the length of time which the work has taken. The field work was mainly done during the summer seasons of the four years from 1900 to 1903 inclusive.

After work in the Champlain valley had been begun by the writer, Mr G. K. Gilbert of the United States Geological Survey, who had previously made an examination of the country from Lake Ontario around the northern slopes of the Adirondacks into the Champlain valley as far south as West Chazy, generously offered to the author through the state geologist the results of his investigation. I have made the freest use of these notes both in the search for localities and as a check on my conclusions, and particularly have I been guided by Mr Gilbert's observations and conclusions in regard to the fixation of the marine limit on the northern side of Covey hill in Canada. The placing of the marine limit from that point southward, however, is entirely on my own responsibility and this distinguished geologist is in no way involved in any mistakes which I may have made in my endeavor to determine the extent, the elevation and the degree of tilting of the ancient water levels described in this paper. In this report no use has been made of the data from the northwestern slope of the Adirondacks other than to include a record of the fossil shells found near Norwood, N. Y. Special acknowledgments are due to Dr F. J. H. Merrill, who has in many ways both in the field and in the office contributed to the work of the author. I have also to thank the officers of the Geological Survey of Canada for numerous kindnesses in the granting of information and guidance, and to Prof. A. P. Coleman for giving me the advantage of his greater experience with ancient shore lines by personally visiting with me some of the critical areas of northern New York.

Chapter 1

PHYSIOGRAPHY OF THE HUDSON AND CHAMPLAIN VALLEYS IN RELATION TO THE CONTROL OF GLACIAL PRODUCTS

PHYSIOGRAPHY OF THE HUDSON VALLEY

The valley of the Hudson river, from the point of view of the stream bearing that name, is a geographic group of drainage slopes whose axial trough, if we except the Adirondack portion of the river, has a nearly north and south direction, traversing a geologic area of variable structure formed of rocks of widely different ages in its various parts, and having different degrees of topographic development. The order and structure of the rocks of its valley have long been portrayed on the geologic maps of the State, and the contour of the land forms bordering the river are now faithfully delineated on topographic maps, but the precise history of the origin of this river has not been determined. The reader must, therefore, be content with a statement of the main facts in the form and cross-section of this valley and it is important that these features should be understood in following any attempt to unravel the Pleistocene history of the valley, particularly in relation to its occupation by the last ice sheet and to the retreat of that ice from eastern New York and the subsequent invasion by the sea of at least the neighboring Champlain valley.

For the greater portion of its length, the Hudson valley consists of a gorge within a valley. Both the valley and the gorge vary so greatly in minor detail from point to point that it is desirable first to generalize the parts in which the valley, as a whole, has something like a characteristic geologic and geographic expression. From this point of view there are four longitudinal divisions of the Hudson valley each with a landscape somewhat peculiar to itself.

Longitudinal divisions of the Hudson valley. The four segments of the Hudson valley above referred to comprise two regions of mountainous relief and two of lowlands, one of the latter being relatively roughened by somewhat advanced dissection.

The first of these segments, including the source of the river, embraces the course of the Hudson within the Adirondack region, which part, for convenience of description, will be called the Adirondack-Hudson river. It is a region of the most ancient rocks in the State and of the highest relief. With this stream, this report is only incidentally concerned.

The second segment includes the river from its point of emergence from the southeastern base of the Adirondack mountains to the northern portal of the Highlands in Dutchess and Ulster counties. It is a lowland region of ancient Paleozoic strata. It is divisible into two segments for convenience of treatment, an Upper and Middle Hudson valley. In this report the Upper Hudson is meant to include the valley from the head of tide and the

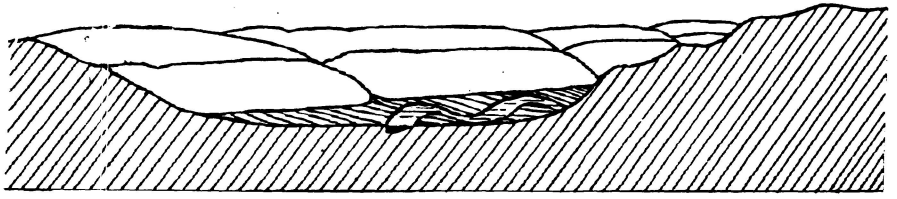


Fig. 1. Early Cenozoic stage of the Hudson valley. The river is at or near base level; it has widened out the rock bottom of its valley to form a narrow plain 2 to 3 miles wide. The stream is probably meandering and more or less alluvium sheets over the bed rock.

recent delta of the river near Troy to the base of the Adirondack mountains. The term Middle Hudson applies to the valley from the head of tide to the northern edge of the Highlands.

From the point of view of the Pleistocene deposits which the Upper and Middle Hudson valleys exhibit the region may be divided into (1) the Fort Edward district on the north, in which the history has several features in common with the Champlain valley on the north; (2) the large tract in which both banks of the river are bordered by the newer brick clays from immediately south of Fort Edward to probably the vicinity of Rhinebeck; (3) the Poughkeepsie district, in which the latest clays are wanting, extending from somewhere north of Staatsburg and the southern limits of the Albany clay district as far south as the mouth of Wappinger creek and the northern part of Newburg, where older clays begin to be heavily developed; (4) the Newburg district, extending from the last southward to the Highlands.

From the point of view of the larger features of relief, this second segment of the Hudson valley is marked by the two great valleys into which it opens on the west along the strike of the Hudson shales and sandstones, the one in the valley of the Mohawk between the Adirondacks and the Catskills on the north, and the other that of the Walkill between the southeastern border of the plateau region and the Highlands on the south.

The third division, the shortest of all, comprises the Highland canyon of the Hudson. It is a region of moderately high relief, comparable in geologic structure to the Adirondack region. This portion of the river valley will be referred to as the Highland-Hudson.

The fourth segment of the river includes the region south of the Highlands to the sea. It is a region of ancient and metamorphic Paleozoic rocks on the east and of mainly Triassic rocks on the west. It may for convenience be known as the Lower Hudson.

For geologic reasons it is convenient to recognize in an ancient now submerged channel traversing the continental shelf to the southeastward of New York harbor a possible fifth segment of the Hudson valley, which may be termed the Submarine Hudson, but to what extent this is excavated in bed rock is not known.

At the northern border of the Fort Edward district, two narrow defiles unite the Hudson valley with that of Lake Champlain; one of these is occupied by Lake George; the other, the valley of Wood creek, directly drains the northern half of the Fort Edward district into the Champlain valley.

The divide between the Hudson waters and those of Wood creek east of Fort Edward is 147 feet above sea level. A depression of 200 feet in the region between Albany and the St Lawrence river would convert the Hudson and Champlain valleys into a navigable strait having a depth sufficient for the largest vessels. A depression of 150 feet at Fort Edward and northward over the region to the St Lawrence and an elevation of an equal amount at New York city would reverse the flow of the Hudson in the lower, middle and upper sections and turn the drainage into the St Lawrence gulf.

Gorge of the Hudson. The Hudson river flows in a gorge of more recent age than its valley proper. The gorge, widened out into a well opened valley in the region of the Tappan Sea, is usually elsewhere steep sided, and throughout the middle and upper segments of the river it has a singularly uniform width and hight of wall above sea level. From the head of tide near Troy the rock floor of this gorge is, except for a few islands, below sea level, thus converting the river from near Albany to the sea into a fiord. As this portion of the floor of the gorge is now and has been for some time in the past receiving sediments, its exact depth below sea level is not known.

Beginning on the south, this gorge is believed to be traceable seaward in the so called submarine extension of the Hudson. Between the 100 and 300 foot fathom lines, the outer, deeper part of

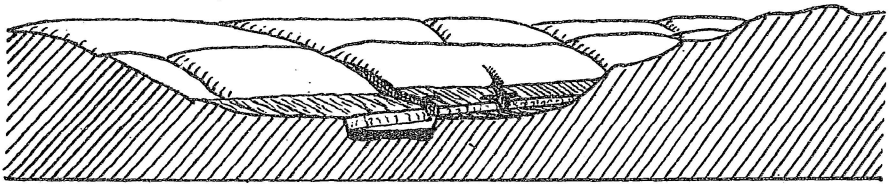


Fig. 2. Late Cenozoic stage of the Hudson valley. The river with the surrounding region has been uplifted an undetermined hight above its old base level; the river has cut a deep gorge to or near the new base level; the side streams have cut lateral gorges, and the surface of the rock terraces has become roughened by incipient dissection. Approximate preglacial condition of the Hudson river valley.

the gorge attains a depth of 452 fathoms. If the view be accepted that this part of the gorge has been excavated by the river when the land was higher than it now is, it is necessary to admit that the coast has recently stood 2700 feet higher in relation to the sea. This elevation, if it can be shown to have taken place during the Pleistocene epoch, must have had important consequences in the distribution of glaciers and their deposits during epochs of glaciation and in the work of streams in the interglacial epochs. Not only the exact geologic epoch or epochs in which this submarine gorge has been excavated is in doubt, but its origin as a subaerial phenomenon has been disputed by eminent writers on the subject of the topography of the continental shelves of the continents.

Remarkable examples of these submarine gorges exist on the east shore of the Atlantic ocean off the mouth of the Congo river,

and in the Gulf of Cape Breton, off the Côte des Landes, France, in such relations to submarine currents as to favor the hypothesis that these channels are unfilled portions of the coastal plain kept open by currents which prevent deposition along the line of these gorges. What seems to be to some writers an unanswerable confirmation of this view is the well marked gorge traversing the delta of the Rhone in Lake Geneva and that of the Rhine in Lake Constance. In the case of these lakes it is impossible to assume since the modern deltas began to form that the rivers flowing through the lakes have by uplift of the lake bottom been enabled to dissect their deltas; it is more reasonable to suppose that the configuration of the outer part of the delta in each case is due to causes now in action. Forel notes that the amount of sediment carried out over the bottom at the mouths of these rivers is too great, and that the process has been carried on for too long a time to permit any antecedent topography to remain. In his opinion these "sublacustrine ravines" are the result of erosion now going on and prove the existence of currents in the bottom of the lakes. He attributes the excavation to the lower temperatures of the river water charged with mud as compared with the temperature of the lakes. In the case of the Congo submarine channel, Buchanan has noted the occurrence of a lower, inflowing salt current in the river preventing in its course the deposition of sediment. Suess claims that in this case it is not so much that the canyon has been excavated as that the sediments have been laid down either side of it, thus building up the continental shelf and leaving a gorge in the path of the inward moving, bottom current of sea water.[1]

It must be admitted that in the case of the submarine Hudson gorge no facts have heretofore been observed on the neighboring land which demand in postglacial times so high an elevation of the coast as does the gorge itself when regarded as a true river-cut gorge. The depth of the bed rock in the Hudson river between New York city and the Highlands would be, if known, a much

[1]For literature on the subject consult Suess, La Face de la Terre, v.2, 1900, p.853–56, with references to papers by Lindenkohl, J. D. Dana, G. Davidson, F. A. Forel, Eberhard Graf Zeppelin, Duparc, Delebecque and others.

more accurate index of the elevation of the coast in recent times than the measured depth of a channel whose origin is subject to some doubt.

The most important light from the immediate vicinity of the mouth of the Hudson concerning high elevation has been presented by Veatch[1] on the basis of borings made in the glacial deposits of Long Island. An elevation of at least 250 feet is indicated previous to the deposition of the Jameco gravels, beds seemingly near the base of the Pleistocene series, but separated from that base on Long Island by deposits tentatively correlated with Professor Salisbury's Pensauken group by Veatch. The whole history is one of alternating elevation and depression above and below the present stand of the sea in relation to the land.

As is frequently repeated in the later pages of this report, the submarine Hudson channel makes it possible to admit high elevation whenever the facts over the land on the north require such an interpretation of its history.

The Hudson gorge from New York city northward is fairly distinct, as far as the vicinity of Fort Edward, where it widens out into the Fort Edward basinlike district; yet over the floor of this basin a shallow but definite rock trench is traceable northeastward along the course of Wood creek to the head of Lake Champlain.

Hudson rock terraces. The excavation of the gorge below the floor of the ancient Hudson valley has left well defined rock terraces bordering the Hudson. The terraces and the gorge have alike been somewhat modified by glacial action, glacial striae being observed very generally along the river banks through the whole length of the valley except in such places as recent rock falls from the steep bank have exposed new sections of the bed rock.

The elevation of these terraces must correspond approximately therefore with the lower levels of the ancient valley floor of the Hudson. The following figures represent the present attitude of the rock terraces between New York city and Fort Edward.

[1]Veatch, A. C. Diversity of the Glacial Period on Long Island. Jour. Geol. 1903. 11:762–76.

ELEVATIONS OF THE HUDSON ROCK TERRACES

Kings Bridge	200
Yonkers	350
Tarrytown	140
Sing Sing	160
Croton	140
Peekskill, Verplanck and Buchanan	140
Garrison	200
Cold Spring	220
Dutchess Junction	160
Poughkeepsie	200
Albany	220
Schuylerville	300
Mouth of the Moses kill	200

The rock terraces bordering the Hudson gorge are rather uniform in elevation. The terraces are higher now on hard than on soft rocks, higher in the Archaean belt of the Highlands and southward to Yonkers and over the Palisades than elsewhere; lower on the soft Hudson shales and slates and in the region of the Triassic sandstones. The lowness of the terrace on the east bank between Peekskill and Dobbs Ferry is accounted for by the former overlap of the Triassic basal beds in this region; but these differences of level are not all accounted for by differential erosion, including glaciation and weathering, as between the hight in the Highlands and about Yonkers. The terrace hight from Sing Sing southward to Kings Bridge appears too high, and in view of the rapid falling off of the terrace level in New York city and as marked by the decline of the Palisade ridge in Hoboken and southward to its pre-Cretaceous level, indicates a local uplift, central about Yonkers.

The narrowness and local absence of the rock terrace within the Highlands is to be taken as evidence of the slower or belated cutting through the Archaean rocks of that district. The terrace is clearly shown, however, at West Point, Highlands Station and Garrisons, and appears to have extended through the Highlands as the old floor of the Hudson valley, thus indicating the existence of a water gap here at a time as remote as the epoch of

base leveling in which the ancient floor of the Hudson valley was worked out.

Davis[1] in 1891 referred the excavation of the Hudson valley to Tertiary time and the cutting of the trench in this lowland to late Tertiary or a post-Tertiary beginning.

Rock channels of the upper Hudson valley. The Hudson gorge is fairly well defined as far north as Fort Edward by the present course of the river. At that point the river falls into this rock channel from the west very much as the Mohawk falls into it at Cohoes, but the rock gorge is traceable north-northeast into the Lake Champlain valley.

The divide today between the Hudson drainage and the Champlain drainage in this gorge lies about 5 miles northeast of Fort Edward and is a scarcely perceptible watershed 147 feet above sea level. It is owing to this feature that the Champlain canal connects the two drainage basins with relative ease and few locks. [*See* the Glens Falls quadrangle for details of the topography]

The present course of the Hudson from the eastern edge of the Adirondacks to Fort Edward is evidently of postglacial origin, for the river runs over ledges at Fort Edward, at Bakers Falls, at Sandy Hill and again at Glens Falls, dropping from the 300 foot contour at the edge of the mountains to about 130 feet at Fort Edward. West of Glens Falls the river has sunk its bed in meanders into the glacial sands which form a delta made on the melting out of the ice which lay in the lowlands in this upper part of its valley. These sands thickly cover the bed rock topography. Whether the river in preglacial times flowed southward so as to join the Hudson gorge at or below Fort Edward or turning to the north just west of Glens Falls and following the valley of Halfway creek emptied into Lake Champlain is at present an open question, which can only be decided on evidence from borings which are at present wanting in this section.

It is evident that Halfway creek flows in a well defined channel but partly filled by the debris of the last ice invasion [*see* Glens Falls sheet].

Ballston channel. From near Schenectady an old rock channel trends north-northeastward by Ballston toward Saratoga. South

[1]Bost. Soc. Nat. Hist. Proc. 1891. 25:318–35.

of Ballston a stream escapes from this gorge by a narrow defile into the circular depression in the bottom of which lies Round lake, a body of water which in turn is drained by a narrow valley into the Hudson at Mechanicville. This system of channels antedates the last ice covering of the district, for portions of the region including the flats bordering Round lake are covered with glacial boulders. Singularly enough these depressions were not filled with the clays of the Mohawk delta stage probably because as will be shown later the ice sheet lay over the region while these clays were deposited on the east and south.

The Ballston rock channel is dependent, in part, on structure. The Hudson river slates, essentially flat on the east of this trough except for small overthrusts, are seen standing vertical within it north of Ballston lake. Erosion in Pleistocene time has excavated the channel along the vertical beds, which are evidently separated from the horizontal strata on the east wall of the valley by a fault. Ebenezer Emmons[1] recognized the existence of a fault extending southwestward from Saratoga towards Schenectady but he makes no mention of the Ballston rock channel.

Round lake channel. The large circular depression in the bottom of which lies Round lake [*see* pl.1] opens eastward through a narrow valley into the Hudson gorge at Mechanicville. Little or nothing is known concerning the real extent of the depression in the bed rocks of which this largely drift-masked cavity is a part. The Hudson river rocks rise on the west between Round lake and the Ballston channel and may be seen in the narrow defile cut by Anthony kill, a stream which now drains the Ballston channel from East Line to the divide south of Ballston lake. The plain between Round lake and Saratoga lake is at least in part a till-covered surface as about Malta. It seems probable that Round and Saratoga lakes are unfilled depressions marking the site of an old valley west of the present Hudson gorge. In the later development of the glacial lakes in the upper Hudson and Champlain valleys the various channels from Fish creek southward through the Ballston and Round lake channels probably will be found on further study to have served as temporary waterways at a time

[1]Agric. N. Y. 1846. 1:135.

PART OF THE SCHENECTADY QUADRANGLE



THE ROUND LAKE REGION

Showing an unfilled area

Scale $\frac{1}{62500}$

1 0 1 2 Miles

Contour interval 20 feet.

Datum is mean sea level.

when the Hudson gorge from Fort Edward south to Albany was not so deeply excavated as it now is.

Wood creek channel. The valley of Wood creek, to which reference will be repeatedly made in this report, forms at present the lowest line of communication between the upper Hudson valley and that of Lake Champlain. The divide between these two valleys lies at an elevation of about 147 feet, near Dunham basin [*see* pl.13]. It will be noted from the map that the old gorge of the Hudson appears to be continued in this direction and that the Hudson river above Fort Edward falls into this broad open channel along a new path characterized by falls and a much less width. As will be noted in a later chapter the Wood creek channel appears to have been for a time the outlet of a glacial dammed lake extending from near Dunham basin northward over the site of Lake Champlain.

PHYSIOGRAPHY OF THE CHAMPLAIN VALLEY

Lake Champlain appears to occupy an irregular depression excavated mostly in the lower Silurian and Cambrian rocks corresponding in this respect to the Hudson in its gorge from Albany southward. The present depth of this erosion feature is at least 500 feet below sea level in the deeper part of the lake. The equivalent of the rock terraces of the Hudson, or the floor of the older, wider valley in which the newer and narrow channel has been excavated, is found along the shores of Lake Champlain in a dissected rock surface as in Essex, along the Vermont shore south of Burlington, and widely developed about the northern part of the lake. This ancient valley floor is about 300 feet above the present sea level. Both this surface and the newer valley excavated in it have suffered more from glacial erosion than has the analogous topography of the lower Hudson valley. The Wisconsin ice sheet pressed into the northern portal of the Champlain valley in a strong flowage coming from the northeast rather than from the north so that the maximum erosion line must have been thrown toward the base of the Adirondacks in the position of the lake basin. No facts are at hand, however, to show how much, if any, the lake basin was deepened by ice action. Many of the streams, such as the Ausable, which now enter the lake over high level rock

benches in lateral valleys owe their present courses to glacial embarrassments. The Ausable has an old valley near Keeseville west of its present course, and the drift filling must be very deep at and above Keeseville.

The deep notches of the Winooski and the Lamoille rivers through the Green mountains, draining lowland basins on the east of this range, correspond in topographic development with the high level valley floors worked out in the Adirondacks, but this stage is apparently older than that of the immediate vicinity of the Hudson and Champlain valley floors.

GLACIAL MOVEMENT THROUGH THE HUDSON AND CHAMPLAIN VALLEYS

The observed striae throughout the Hudson and Champlain valleys, accord closely with the direction of the axis of this great depression and with the expansion and contraction of the valley walls. Throughout the entire district the direction of transportation of debris, the arrangement of the glacial deposits, the form of roches moutonnées and every feature indicative of glacial erosion points conclusively to the general southward movement of ice from the broad open northern expanse of the Champlain valley southward.

Along the New York shore of Lake Champlain there is marked tendency of the striae to turn southwestward, indicating a movement of the ice upward over the basal slopes of the Adirondacks as the ice became pressed within the narrowing southern part of the Champlain valley. At Port Henry this tendency is so marked that it may be doubted whether further detailed examination of the region back from the lake may not show the existence of local glaciers moving down the slope so as to produce the eastwest striation seen just south of the town [*see* p.156].

Through the southern arm of Lake Champlain the ice moved southwestwardly through the defiles of the mountains and out on the plain about Fort Edward. This southwestward movement is well shown at Glens Falls where striae have a course n. 63° e. Thence the movement was southward through the Hudson valley. About Albany the ice appears to have backed up in its advance against the Helderberg escarpment on the south and west. It has long been known that, in this latitude,

the ice pressed southeastwardly over the state line into Massachusetts. Pressing southward through the Hudson valley the Highlands must again have profoundly influenced the movement of the ice both in its retreat and in its advance. The ice passed through the Highland gorge leaving a characteristic glaciated topography in the smoother northern slopes of the high ridges which overlook the river and plucking out boulders from their southern slopes, thus giving the frowning cliffs which meet the eye as one ascends the river. The extension of the lowland developed over the soft Hudson slates to the southwest along the northern side of the Highlands would have afforded a passage for the ice in that direction. The ice passing through the Highlands and at the maximum of glaciation over the highest ridges, must have had a relatively rapid motion through the lower Hudson valley. The axis of this flow passed, as Salisbury has shown by detailed mapping of the striae, to the west of the Palisade border of the gorge over the Hackensack lowlands of New Jersey. On the west of this line the ice moved southwestwardly over Newark N. J., and on the east of the line southeastwardly over New York city to the moraine on Long Island.

The form of the valley and the Hudson gorge must have influenced strongly the retreat of the ice, and many of the glacial deposits, described in the following pages, demonstrate this point so clearly that, in view of the light which they throw on the several stages of the melting ice as it dwindled away from a complete covering of the eastern part of the State to long tongues of ice comparable to a valley glacier, it becomes possible to outline the history of the retreat in relation to the varying cross-section of the Hudson valley and in regard to the control which the distribution of the ice mass exerted on the character and order of arrangement of deposits made either by the ice in moving debris to its margin, or by the streams which built deposits along that margin.

THEORETIC MODE OF RETREAT OF REGIONAL GLACIER FROM A VALLEY

Enough is now known of regional glaciers such as that which spread from the region north of the St Lawrence into New England and New York to enable us to depict the general mode of retreat of the ice sheet in different districts, having deep meridi-

onal valleys on the one hand like that of the Hudson and broad uplands or sea border plains, on the other such as occur over central and southeastern Massachusetts. Here we are solely concerned with a long, well defined meridional valley.

As the ice front retreats northward there is found evidence of its having halted from time to time at certain places long enough to build moraines of dumped and shoved material on the one hand, and to allow the construction, from the outwash of sands and gravels, of deposits of these materials in the form of plains, cones and deltas more or less sharply marked on their northern or iceward aspect by evidence of deposition against or in the presence of masses of melting ice. The ice melting out back of such accumulations, either moraines on the one hand or outwash plains on

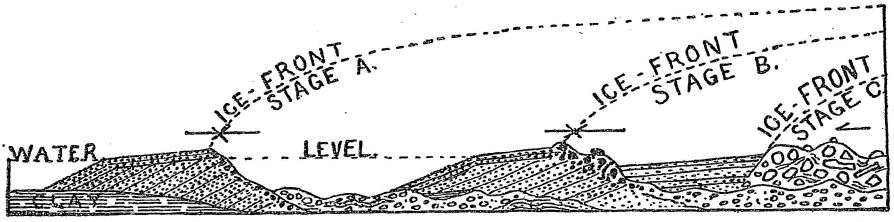


Fig. 3. Successi on of glacial deposits during retreat. Theoretic distribution of glacial deposits from north to south in New York and New England: *A*=stage in which a moraine has been formed and is confronted by an overwash plain; *B*=overwash and outwash plains; *C*=a later morainal stage with outwash sands.

the other, may have left but a veneer of till or gravel over the glaciated bed rock. At an indefinite distance to the northward other frontal accumulations will appear marking the next stage in the retreat.

In the case of these deposits the coarsest detritus of glacial origin will appear next the ice front of the time in the form of till or of coarse gravels and sand; farther away in the direction of the flowing waters finer sands will appear and still farther away the clays which remained for a time in suspension. The succession of deposits will appear as in the above diagram [fig. 3.]

If the deltas are built in standing water their outer lobate margins will indicate the approximate hight of the water plane of the time, be it sea level or lake level. If building takes place on an area from which the waters escape to the sea without ponding,

alluvial fans will form with their outer margin blending indefinitely with stream level as in the stage numbered C.

So long as the ice sheet fills the valley and covers its divides, terrace building within it is precluded. As soon as the ice has retreated it will also have thinned, and the time will come when a long tongue of ice fills the valley. Reflection of heat from the bare rock walls will cause the ice to melt most rapidly on its margins. Along these marginal depressions with rock walls on one side and ice walls on the other the drainage will escape. Temporary lakes may form in this situation whether the ice be in motion or stagnant. The situation will then appear somewhat as follows [see fig. 4].

Into these marginal troughs will be carried sands and gravels by side streams coming from the uplands now freed from ice.

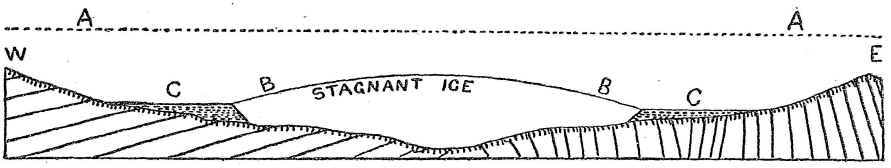


Fig. 4 Cross-section of valley with marginal glacial deposits. Theoretic condition in meridional valley back from the ice front when glacial has thinned in the form of a long tongue of ice or valley glacier: *A*=maximum development of regional glacier; *B*=surface of the ice at any given stage of thinning during retreat; *C*=site of lakes and deposits on margin of glacier.

Along these depressions will also sweep the lateral streams. The evident tendency will be to build deposits of gravel and sand in the presence of the ice as in ordinary stream beds with a slope toward sea level, but owing to melting ice with perhaps sudden changes of level causing lower and lower stages of gravel and sand building toward the mouths of the streams. When the ice melts out, these deposits will form terraces with margins reflecting more or less the form of the ice sheet against which they were constructed. The effects may be reproduced at successively lower levels marking stages in the evacuation of the valley. These stages should be correlated with frontal moraine or delta stages. Marginal remnants of the ice sheet might lie out for some time to be surrounded by gravels and sands, thus giving kettle holes and ice block holes in the contemporaneous ice-bound terraces, when the ice finally disappears.

In case the sea invaded such a valley during the ice retreat, it would control to a certain extent the deposition of washed gravels on the sides of the ice tongue but, unless the submergence were very great as compared with the depth of the valley, local embarrassments to seaward drainage would undoubtedly occur. Such embarrassments would arise where spurs entered the valley between side streams, or where the ice melted less rapidly, thus giving rise to levels of building above sea level.

Application of theory to the Hudson valley. The peculiar form of the Hudson valley, its rock benches or terraces inclosing a deep gorge, and the Highlands through which the river passes by a narrow defile with a constricted development of these benches, must have affected in a marked manner in its different sections the mode of retreat of the ice margins and consequently the distribution of the sediments laid down in the presence of the ice. First the north and south depression through the Highland section whether or not a continuous river valley as in postglacial times would have guided a strong current of ice southward and during the period of final melting would have given rise to a long tongue of ultimately stagnant ice occupying the valley north of the Highland gorge.

It is to be presumed that the barrier opposed to ice movement by the Highlands would have led in the advance, as in the retreat, to a stage when the moving ice banked up against the northwestern wall of the Highland ridges would have poured through the defile at West Point as a small valley glacier spreading out on the rock terraces below Peekskill or pushing south wholly confined within the Hudson gorge; at least in the retreat this was the case when certainly this gorge had its present general cross-section.

Wherever during the retreat the ice front crossed the river and deployed on the banks to the east and west, the streams discharging from the ice would bring down heavy loads of clay, sand and gravel, and bank them up against the ice front in the river gorge and over the neighboring rock terraces. Such deposits might originally completely fill the gorge, to be subsequently partly removed in the renewal of ordinary river drainage in the area.

When the ice had thinned so as to form a long narrow tongue filling the lower portion of the valley, covering the gorge and a considerable breadth of the rock benches on either

side, the streams from the neighboring open country would build their deltas against the ice margin in the form of terraces involving buried shreds of the ice margin, and having when the ice melted away kettles or depressions marking the sites of these buried or partially inhumed ice masses, and a relatively steep but perhaps hummocky or kamelike terrace front overlooking the river gorge and at varying distances from and elevations above the gorge. The water thus impounded against the ice margin would flow along the ice edge or finding its way through crevasses and water tunnels in the ice escape with the glacial drainage without producing marginal stream phenomena.

Finally when the ice had melted off from the rock terraces for a time a long narrow tongue would still occupy the gorge itself forcing some of the drainage over the rock benches and covering them with sheets of clay, sand and gravel. This coating of glacial materials might here and there mantle the ice in the gorge where that had been lowered by melting so that its surface lay below the level of the rock terraces. In any event when the ice finally melted out of the gorge the rock benches would be coated with terrace drift to their edges, the deposit here and there descending into the gorge as if it had once entirely filled it though this may never have been the case. Unless the evidence of ice contacts be found, it would be an extremely difficult task to determine with certainty the original extent and limits of such deposits and to discriminate them from remnants left from a reexcavation of a gorge which has once been filled by glacial sediments.

Moreover, such lateral glacial deposits will depend for their elevation on the hight of the rock terraces on which they have been spread out. From point to point they should merge into the frontal deposits of the successive stages of the retreat of the ice front. Along such frontal lines the materials would be coarsest, gradually passing to finer and finer materials toward the south or away from the ice if the drainage was in that direction. Here and there lateral tributary streams would pour in their contribution of detritus and produce local variations of texture or thickness of the sediments.

If the ice retreat by successive oscillations in which the recessional movements overbalance the forward ones, the complica-

tions in the sedimentary history will be greatly increased. The glacial clays laid down in the outer belt of deposition of one frontal stage may be eroded by the overriding action of the ice of the next and then sheeted over, partly or wholly, by deposits of till or boulders as well as by sheets of coarse gravel and sand.

Another effect producing local terraces will arise during the melting of ice from a gorge like that of the Hudson with dissected walls quite independently of sea level so long as the rock terraces rise somewhat above sea level. As soon as the ice is limited to the main gorge, the embayments in the wall, receiving drainage from the ice and such lateral streams as may pour into them from the open country, will form temporary lakes and be filled and sheeted over with sands or gravels at levels determined by the effectiveness of the ice barrier and the duration of the process of filling, as well as by the elevation of the floor of the area of deposition.

Successive stages in the cross-section of a melting glacier in a valley like that of the Hudson river. The glacier which covered eastern New York, it may be said, was pushed on to the area by the pressure of its own accumulation in the Laurentide district. Eliminating the effect of forward motion in the ice and supposing the glacier to have been stagnant over the region between the Highland canyon of the river and the Catskill mountains, it would follow that for some time during the declination in the thickness of the ice sheet the relations to the valley would be those indicated, in figure 5, in which the ice sheet not only filled the valley but covered the divides on either side.

For a long time after, when the ice had dwindled down to a tongue filling the bottom of the valley, its cross-section would have been that shown by *BB* in figure 5 and this general cross-section would have been retained till a final stage was reached, when the ice filled the gorge only leaving the top of the rock terraces free for lateral drainage.

In this final stage the cross-section would be that shown in *DD*, figure 5, in which the broad rock terraces might become the seat of lakes and lateral stream deposits. Upstream and behind constrictions in the valley where the terraces became wedged out as in the Highlands, by unconsumed spurs from the valley sides,

lakes might arise in which the deposition even of clay would become possible.

During the first stage when the entire district was ice covered, water-laid drift would be limited to subglacial stream deposits including eskers and probably some kames; during the second stage when the drainage from the top of the ice and from the valley sides could escape laterally between walls of ice and rock, deposition might take place high up on the valley sides in the form of lateral moraine terraces, lateral kame terraces and deltas built by streams coming off the ice or down the valley sides, but the iceward margins of these deposits would be subject to derangement from the further melting of the ice. In the last stage, when the ice became confined to the gorge, the rock terraces on either side

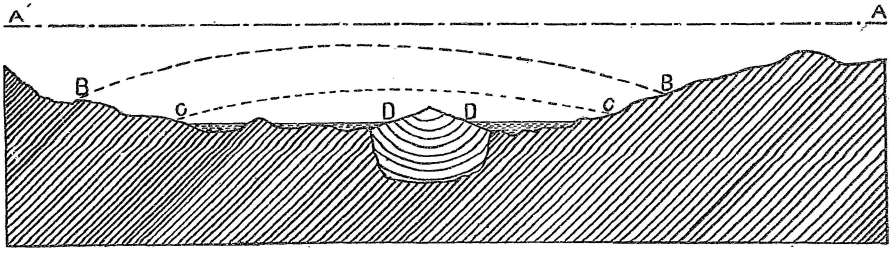


Fig. 5 Cross-section of dwindling ice sheet in middle Hudson valley at different stages in relation to the valley form. *AA*=maximum development of ice; *BB*=local ice; *CC*=ice reduced to a glacier covering old valley-floor; *DD*=ice remnant filling gorge only

would become the seat of lakes and open-air streams with a great variety of deposits. Such deposits would resemble river terrace deposits but near the edge of the gorge they would probably display coarser materials fed on to the rock terraces by the melting of the ice. Kettles and kames would occur here and there where deposition had taken place over and about the fringe of ice lapping over on the rock terrace.

The effect of any slight forward movement of the ice during the progress of melting would simply tend to maintain the ice margin longer at any one position and thus favor the greater development of the deposits at that stage, for forward movement if due to supply of ice from behind would both thicken the ice and increase the length of the glacial tongue.

The effects of the second or valley stage offer no difficulties of recognition, but in the third or gorge stage of the ice remnant it is necessary to discriminate the lateral masking terraces which

may originate in this way from terraces resulting from the reexcavation of a gorge completely filled by extraglacial clays or other materials after the ice has vacated the immediate district. Figures 6 and 7 illustrate these conditions in their simplest mode of occurrence.

In the former case coarse gravels and sand would be expected to predominate as the direct result of the outwash from the melting ice lying in the gorge but rising above the level of the terraces. Clay making would go on only in lake-like expansions above constrictions in the valley or downstream in the extraglacial field of that stage. The iceward margins of such clay deposits would pass into coarser

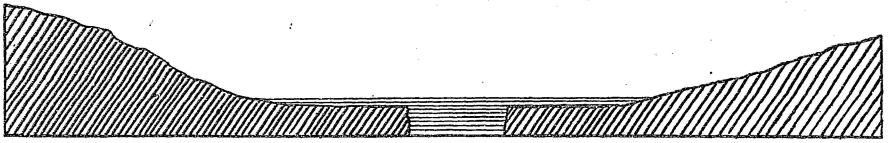


Fig. 6 Valley floor and gorge filled with clays

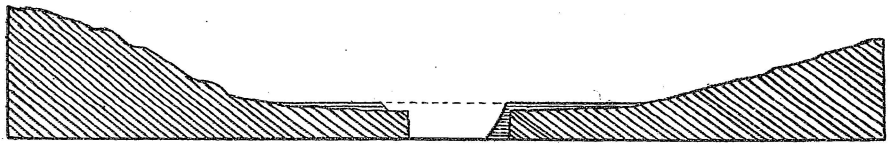


Fig. 7 Reexcavation of gorge, showing variable erosion of clays from opposite banks

detritus coming from the ice margin. Both sands and clays would fail to be deposited in the gorge except where the ice remnant receded by melting from the sides of the gorge, a condition which might locally occur before the ice shrank so much as to permit drainage altogether through the gorge. The distinguishing characteristic of such deposits would be evidence of contact with the ice sheet along the edge of the gorge, locally coarse deposits in that position, and the failure of remnants of these deposits to appear in the gorge except in alcoves and recesses or side channels not held open by the ice.

The distinguishing features of an excavated filling would be sought in the equality of hight of flood plain deposits on opposite sides of the gorge, the essential identity in the lithologic characters of contemporaneous sections on opposite sides of the gorge, and in the occurrence of remnants of the deposits in any part of the gorge protected from subsequent erosion.

Chapter 2

RETREAT OF THE WISCONSIN ICE SHEET FROM EASTERN NEW YORK

In this and the following chapters which deal with the evidences of the retreat of the ice sheet from the Hudson and Champlain valleys, the aim has been rather to determine the conditions of the drainage and water levels at the front of the ice sheet than to attempt a presentation of a full account of the successive stages of the ice retreat. Many additional facts, such as are presented here, concerning gravels and sands deposited about the ice margin in the Hudson and Champlain valleys remain to be described and located on maps.

The data concerning water levels derived from deposits made at successive stages in the retreat of a glacier must necessarily pertain to a series of water bodies whose levels may or may not have been permanent as the water extended itself into the area abandoned by the retreat of the ice front.

In relation to the very beginning of the ice retreat, there are two classes of evidence bearing on the position of sea level at the mouth of the Hudson river, one of these categories of fact lies outside the glaciated area, the other lies inside that field and forms the body of matter with which we are concerned.

Extraglacial evidence of water levels. At the time of the culmination of the late Wisconsin epoch when the ice sheet stood farthest south and at New York Narrows, the question arises whether the sea was where it now is, or whether the land stood higher or lower in relation to sea level. Of the geologic evidence outside of the glacial deposits of this epoch, there are three localities within a few miles of New York city which were examined critically with reference to this question. These localities comprise the vicinity of Cheesequake creek, on the Monmouth county shore of New Jersey, the small unglaciated area of Staten Island N. Y., and the ridge which extends through Far Rockaway on Long Island N. Y.

Terrace at mouth of Cheesequake creek, Monmouth county, N. J. Cheesequake creek occupies a valley about 2½ miles long and with an average width of 1 mile from near its mouth on the beach of Raritan bay to its head. Except for small streams entering on the northwest near its mouth and on its eastern side from the

radial drainage area of Morristown, Cheesequake creek receives no affluents adequate to account for the development of a valley extending southwestward into the mainland at this point on the coast. This abnormality is the more striking from the fact that in those parts where streams might be expected, the land slopes away from the depression and streams flow on that slope to the South river or to the Raritan itself. Everywhere about the margin of the cove steep slopes prevail without that adjustment which occurs in the drainage outside of the area, showing that the basin is more recent than the drainage furrows which surround it. In general form, in its relation to side streams and to the surrounding nonglacial topography, this cove resembles what appears to have been the original condition of those indentations of the north coast of Long Island which have been occupied and somewhat enlarged by the ice of the last advance. The creek is newer than the plain and is evidently drowned beneath the sea level by recent sinking.

Along the shore at the mouth of this cove are well defined terraces, the remnants of a plain about 30 to 40 feet above the present sea level. This plain has been dissected and partly destroyed by the erosion of the cove, and it has been cut back by the sea, so that its slope and its initial seaward margin are now indeterminate.

The upper portion of this plain on the west side of the creek consists of coarse yellow gravel lying on Cretaceous clays. On the east side the underlying deposits rise to the surface of this plain, which cuts across different beds thus showing that it is a plain of denudation. The point to be determined is whether this plain is due to marine or aerial erosion, or in other words whether it can be taken as an index of the attitude of the land in recent geologic time, and if so what was that attitude and when was it taken. The fact that there is no equivalent of this plain in the glaciated area shows that it is earlier in origin than the culmination of the Wisconsin epoch and hence makes it presumable that the land was then and has since been unsubmerged.

The topographic map exhibits a number of terraces along this coast from Perth Amboy around the Neversink Highlands to the mouth of Shrewsbury river, whose elevations vary from 40 feet downward.

Unglaciated area of Staten Island. Two very distant small tracts within the State of New York lay beyond the reach of the last ice advance; one in the extreme southwestern part of the State, the other an area about half a square mile in extent at Garretsons and Grant City on the southeastern face of the serpentine hill of Staten Island. On a sloping shelf ranging from 120 to about 250 feet above the sea lies an ancient pre-Wisconsin surface of weathered products surrounded on the northwest by the terminal moraine and on the southeast in the low grounds by the outwash gravels of the Wisconsin ice sheet. The iron crusts segregated in the weathering of the bed rock encumber a reddish soil unmixed with exotic material and topographically unaffected by any sign whatsoever of other agents than the meteoric conditions to which the areole is now exposed. The soft erodable materials form an escarpment descending from the 120 foot line to approximately the 50 foot contour line along which they disappear beneath the fresh gravel of the last ice advance. It is difficult to admit a transgression of the sea, however slight, over this surface without some trace of its action being left behind. This area appears to the writer as a monument of long continued land conditions, beginning before the Wisconsin epoch.

Far Rockaway ridge, Long Island. The outwash plain of the terminal moraine on the south side of Long Island is interrupted at Linwood by a singular ridge of gravels which extends southwestward to Far Rockaway inclosing behind it Jamaica bay. In a recent publication of the museum I recognized this deposit as being older than the terminal moraine and its outwash plain, and from my failure at the time to find granitic pebbles in the gravels referred the deposit to the pre-Pleistocene series. At about the same time Professor Salisbury[1] in a publication of the United States Geological Survey described the deposit as a shallow water formation practically contemporaneous with the outwash plain thus including it in the Wisconsin epoch and inferring from it the presence of the sea, if I understand his position correctly, at a somewhat higher level than now along the southern border of Long Island. Later I visited the ridge with Messrs Fuller and

[1]Salisbury, R. D. New York City Folio. U. S. Geol. Sur. 1893.

Veatch of the Geological Survey and with them found feldspathic pebbles, which would in my opinion place the deposit within the Pleistocene series of Long Island. Messrs Fuller[1] and Veatch[2] now regard the deposit as an exposure of the Manhasset series, presumably pre-Wisconsin, and I see no reason at present for not accepting their conclusion. The deposit is necessarily mentioned here on account of its supposed bearing on the marine limit at the mouth of the Hudson. These recent investigations show, it seems to me, that the Far Rockaway gravels even if deposited beneath sea level long antedate the retreat of the Wisconsin ice sheet.

INTRAGLACIAL EVIDENCE OF WATER LEVELS

The following notes on particular localities by no means give a complete diagnosis of the retreatal stages of the Wisconsin ice sheet. In none of the cases have the ice margins been traced away from the floor of the Hudson valley to the higher levels of morainal accumulation and marginal drainage which undoubtedly can be traced when detailed mapping is undertaken. The account begins with the outermost moraine on western Long Island and on Staten Island.

Terminal moraine and outwash plains. The terminal moraine on western Long Island is confronted on the south by a gently sloping creased plain of gravel and sand sheeting over older glacial gravels and deposits of Cretaceous age. The surface of this plain is apparently in the state in which it was left when the ice retreated from the crest of the moraine on its northern limits. Its southern margin, now below sea level, exhibits along the shore line unmistakable signs of recent subsidence. Thus at Babylon, dredging in the drowned outer portion of one of the creases brought up abundant land vegetation from a depth of 10 feet of water. That the material was not transported and deposited was shown by the growth of roots in the peaty layer which formed a part of the mass. Similar facts have long been well known.

Port Washington and College Point deltas.[3] At Port Washington on Long Island north of the terminal moraine is a well

[1] Fuller, M. L. Resurvey of Long Island. Science.

[2] Veatch, A. C. Diversity of the Glacial Period on Long Island. Jour. Geol. 1903. 11:762-76.

[3] *See* N. Y. State Mus. Bul. 48. 1901. p.653–59.

defined delta of sand with an ice contact slope on the north marking the position of the ice front against which the deposit was built by outflowing glacial water. The level of this deposit is 80 feet above the present sea, but in such relation to the surrounding geography that it clearly has been built in a temporary lakelet held in back of the terminal moraine over the site of Manhasset bay.

Farther east and at the lower level of about 40 feet above the sea there is a much smaller delta with a kame habit on its northern margin built as far as can be judged at a later stage in the retreat of the ice sheet. The internal structure of this deposit has shown a lower plane of water level at about 35 feet. These deposits on the northern flank of the terminal moraine have such discordant levels for stages of deposition which must be regarded as nearly though not exactly contemporaneous that it seems highly improbable that their water levels coincided with sea level at that time.

Glacial delta near Perth Amboy. East of the railroad crossing between Perth Amboy N. J. and Maurer at a point about 1000 yards south of Maurer station, a small rounded spur of sand with an elevation of about 30 feet projects eastward and slightly north on an embayment of the marsh of Arthur kill. The deposit is a spur from the moraine-covered clay beds of the terminal moraine. In the spring of 1901 this deposit was being cut away for the sand which it contained. The section displayed in April, when visited by Dr F. J. H. Merrill and myself, well defined topset beds from 3 to 4 feet thick overlying the truncated edges of foreset beds dipping about 32 degrees east with a little northing, displaying the typical structure of a delta, whose water level must have been at about the 30 foot contour line according to the reading by the map.

The outer slope of this deposit is rather more subdued than in the normal sand plain lobes of southern New England and suggests modification by standing water. From the base there is a slight projecting terrace 5 or 6 feet above tide level. The form of the whole deposit was so ill defined that without seeing the cross-section I should not have taken it for a glacial sand plain. It is evidently related to the deltas above described.

Deposits near Pelham N. Y. Hutchinson creek is a small stream entering Long Island sound at East Chester. From Pelhamville southward to East Chester the stream is bordered by terraces of glacial material, somewhat effaced by postglacial erosion. The terraces stand at an altitude of about 60 feet at Pelhamville and descend to or near sea level at a distance of 2½ miles. In the upper part the deposit is coarse gravel, with boulders intermixed along the contact with bordering outcrops of gneiss and schist. Below the 40 foot contour on the south the materials are conspicuously finer.

In the 20 foot terrace on the east side of the stream there is a frequent cross-bedding from 6 to 10 inches thick with the dip of the cross-beds to the southeast, and this invariably so, indicating continuous current movement such as that of a strong flowing stream of water. The entire section recalls that of the glacial outwash. The slope about 30 feet to the mile is rather steeper than the distribution of the materials would indicate for a stream flowing into the present sea level. If the water level was then at about 20 feet, the slope of the terrace back of and above this limit would accord with the slope of outwash plains.

Englewood sand plain. Salisbury in his work in New Jersey in 1894 described many ill defined but recognizable glacial outwash deposits made in succession in the retreat of the ice across the interval between the Palisades and the Orange trap range. One of the most notable of these accumulations is that extending from Highwood through Englewood, forming the divide between the waters flowing southward into Newark bay and those flowing northward through the Sparkill cut into the Hudson.

A line of kames extends northeast and southwest along the head of this deposit, turning northward along the east side of the Northern Railroad of New Jersey and merging into the drift at the base of the Palisade slope. The elevation of the plain at the southern margin of the narrow kame belt is about 60 feet. Thence the plain slopes southward to about 40 feet in Englewood Center, gradually descending to 20 feet in the southern part of that town. At one point on its eastern margin in the stream valley which borders the deposit, topset and foreset beds were seen in my visit, indicating a water level at about 30 feet.

The frontal margin runs out into a long spur on the western side ending at about 20 feet above the present sea level. In front of the plain is a flat of fine sands. A well sunk in April 1901 southwest of the railroad station reached rock at 67 feet. Above the rock was "hardpan," and above that about 10 feet of clay.

Van Cortlandt park plain. The parade ground at Van Cortlandt park on Tibbits brook in the northern part of New York city is a somewhat modified natural plain or terrace whose surface is about 20 feet above sea level. It is composed of glacial sand and gravel and is of either late glacial or early postglacial date. The surface of the plain now shows no trace of kettle holes, and the slope to the stream on the east and south has no decisive character except it be nearly in front of the ancient manor-house where the slope is marked by a few headstones and also along the southern end of the plain. A few coarse angular pieces of drift rock lie on the slope near the old gravestones. This fact and the manner of ending of the plain in this direction on the broad open valley of a sluggish tidal creek suggest that the plain may have been built in waters confined by a melting remnant of the glacier. It should be borne in mind, however, that direct evidence of the deposition of such gravels and sands in some part of their margin against masses of ice does not in such a situation as that of the Cortlandt park plain exclude the possibility of the water level, if such there was to control its upward growth, having been at sea level.

Certainly the sudden ending of the deposit on the south in a terrace without delta lobes and without evidence of having been brought to this form by the excavation of the drift in the valley below this point makes it probable that the valley toward the Hudson was ice filled, and thus entirely possible that the deposit was made above sea level. In short, the plain at Van Cortlandt park does not demand a higher stand of the sea than that now existing.

Tappan moraine [*see* pl. 2]. The first definite morainal accumulation in the Hudson valley north of the Narrows is encountered on the west side of the Palisades immediately north of the New Jersey boundary in the village of Tappan. At this point the Palisade trap ridge is deeply dissected on a northeast-

southwest line at Piermont, through which cut a small stream now drains the marshes back of the Palisades into the Hudson. The morainal deposits stand above this swamp in the form of two northeast and southwest ridges of mounded drift rising from 100 to over 120 feet above the sea level. They are both cut off by a small stream on the west of Tappan village.

The northern of the two ridges is nearly straight in its course, its southern slope being more uniform in direction and steeper than its northern.

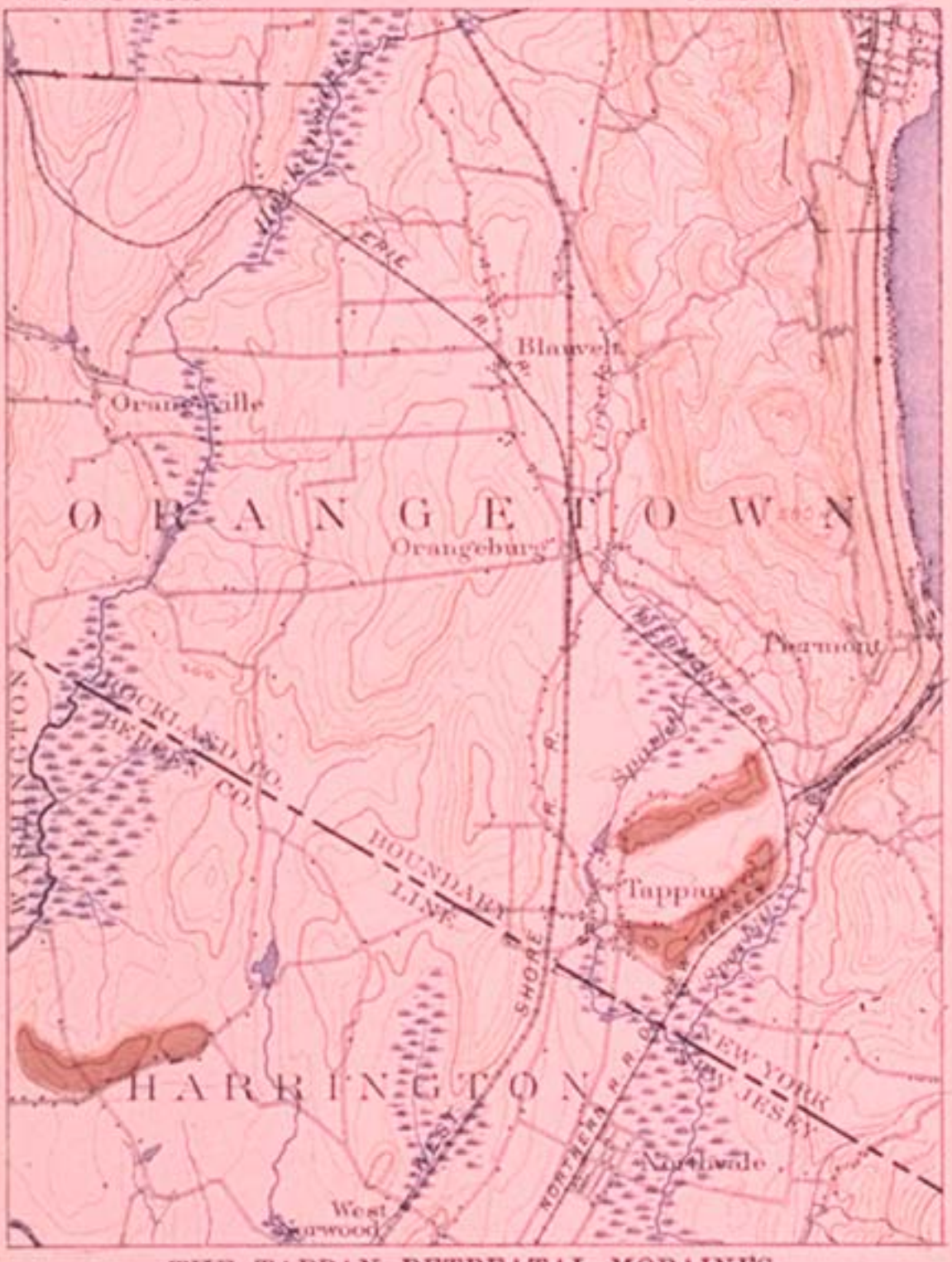
The southern ridge trends southwestward from near Sparkill railroad station for 1 mile when it turns abruptly northwestward into the village of Tappan, having thus a convex southward curvature as seen from the north though its southern front is decidedly angular.

Both of the ridges are composed largely of red gravelly drift. An excavation just south of the Sparkill railroad station showed gravels and sands with occasional small boulders, the upper part of which deposit is without stratification. The surface of both ridges is comparatively free from kettles but carries many boulders, now particularly noticeable about the houses.

A nearly smooth water-laid drift plain lying between 60 and 80 feet above sea level separates the ridges, and drains to the westward; but more significant is a small frontal apron of washed gravel and sand which extends beneath the swamp at the southwestern end of the outer or southern ridge, sloping from about 60 feet at the edge of the moraine to 40 feet where it disappears southward beneath the recent swamp accumulation, fixing the upper limit of the water body or lake into which it was built as lower than 40 feet at the time of this stage, but giving no closer index of sea level.

The position of these frontal moraines, just north of the Piermont gap, plainly indicates that at this time the gap was free from ice, presumably allowing the escape of the drainage as now into the Hudson gorge; nor does the Hudson river appear to have flowed through this gap since the ice last disappeared from its valley. Just east of the Sparkill station glacial striae on the trap rock read n. 24° w. a direction about at right angles to the moraine showing that, though the striae may have been made

PART OF THE TARRYTOWN QUADRANGLE



THE TAPPAN RETREATAL MORAINES.

Scale 1/125000

1 0 1 2 Miles

Contour interval 20 feet.

Datum is mean sea level.

Frontal moraines.

before the moraines, when the ice ran to the south, the direction of ice motion had scarcely changed at this locality during the retreat from the terminal moraine.

West of Tappan in New Jersey other frontal deposits similar in form to the morainal ridges at this place occur in the form of a crescent open on the north, indicating the position of the ice front at this stage in that direction.

The extension of the ice front east of the Hudson at this stage is not clearly shown by any facts now at hand.

The moraines at Tappan N. Y. and in Harrington N. J. appear by their alinement to be synchronous deposits. The water-laid drift confronting the Tappan deposits rises to 60 feet above sea level, but the plains confronting the Harrington deposit appear to rise to 100 feet. It is evident that these slopes of washed drift were not controlled by one and the same water level. Sloping plains and fans of drift are built up along certain ice fronts and along the flanks of gullied mountains, independently of water levels, to quite different altitudes above the stream beds at their base. It is therefore legitimate to suppose that these deposits may also have developed without regard to sea level or lake level, so that the sea level of the time may have been at or below the level of the lowest of these diluvial fans.

Nyack terraces preglacial (pre-Wisconsin). There are two well marked terraces in the vicinity of Nyack on the west bank of the Hudson, but these are so many benches formed by the Triassic sandstones outcropping beneath the Palisade trap sheet. They are everywhere except in the southern part of Nyack covered by glacial till. The lowest of these terraces is about 80 feet above sea level. The red sandstones crop out in a low bluff on the water's edge south of the village. The upper terrace is strongly marked between 180 and 200 feet and corresponds closely to the rock terrace of the Hudson at many points. Another less extensive terrace occurs south of Hook mountain between 280 and 300 feet.

On these terraces the drift is largely reddish till derived from the red sandstone and shale. For about 50 feet above sea level the surface drift is grayish and clayey, as if the ice had smeared earlier glacial clays over the rock benches.

The phenomena shown at Nyack, so far as my observations go, afford no indication of sea level since the retreat of the ice sheet different from that now existing, though this evidence is wholly negative in regard to a recent rise of the water level.

Tarrytown delta. At Tarrytown, Pocantico brook (Gory brook on the United States Geological Survey map) has cut deeply through a deposit of sand forming its ancient delta on the margin of the Hudson gorge. At Tarrytown the eastern wall of the Hudson gorge changes its course from a few degrees east of north to nearly north, and at the same time the rocky wall advances slightly to the westward. In this angle of the bank below the brim of the ancient rock terrace on the northern edge of the town lies the deposit named.

The surface of the deposit is about 60 feet above sea level, rising in a small mound to above 80 feet. On the north it is bounded by steep slopes, in part cut back by the stream which flows at its base and in part an original depression evidently marking the presence of ice while the sands were being deposited.

Deposits south of Croton point. The ice which covered the Hudson valley south of the Hudson Highlands assumed a lobate margin at the time of its halt along the line of the terminal moraine. The axis of most rapid motion in this lobe lay on the west side of the Palisade trap ridge in the Hackensack lowland of New Jersey. East of this line the ice moved southward and eastward across the lower Hudson; west of the line the ice moved to the southwest at angles somewhat greater than the southwest course of the lower portion of the Hudson itself. During the retreat of the ice from the moraine toward the southern edge of the Highlands it is to be presumed that the same general bottom movements of the ice would have been maintained till the ice thinning over the Highlands continued to push through the Highland gorge alone and thus became restricted to a small glacier occupying the Hudson gorge.

The margin of this small glacier it is believed is found in the frontal deposits at Croton point and in the vicinity of Haverstraw; but the deposits south of this stage in the retreat pertain to the broader development of the ice sheet which had not as yet lost its marginal continuity with the ice sheet extending eastward

over New England and westward over the Highlands of New Jersey. In the retreat from the terminal moraine however it is to be expected that the lobate form of the ice in the lower Hudson would be retained, and since the axis of the lobe lay in the lowlands west of the Palisade ridge the east margin of the lobe in its retreat would first uncover the east bank of the Hudson from New York city northward and then the western bank of that river. This relatively earlier opening of the east bank of the river would permit of the drainage from the open country in Westchester county pouring in against the ice margin so as to make deposits partly built against the ice either within the open parts of the gorge or within the dissected rock terrace itself. On the contrary, on the west bank no such deposits would occur, largely because of the lack of an open land slope toward the Hudson.

In this lower section of the Hudson the stratified glacial deposits are restricted to the east bank in situations suggesting in their form and distribution their constraint by the ice margin.

The slight mounding of the deposits at the head or ice contact of the outwash plain at Englewood and again near Tappan village show that the ice at these stages of retreat was slightly quickened and advanced on its frontal outwash deposits, movements which would have extended to the eastern margin, accounting for some distribution there of till over stratified deposits and a slight shoving of stratified beds into disturbed positions.

This inequality of the distribution of stratified deposits is shown elsewhere as on the banks of the Taunton river near Fall River, Mass., where stratified drift, locally a kame terrace, flanks the south side of that southwesterly trending arm of the sea while till without signs of water modification covers the other bank quite down to sea level.

The rule in such situations is that when the ice is retreating with its front nearly or quite parallel to a river valley the bank which is first uncovered by the ice will receive outwash from the ice and inwash from the confronting land while the opposite bank may be left strewn with the ill assorted or unstratified boulder-bearing drift dropped by the ablation of the ice. On the open side of the valley, terraces and kame terraces may thus be formed at levels independent of the sea but above its level.

All the terraces and plains in the lower Hudson south of Croton point, those at Port Washington, College Point, Maurer, Tarrytown and Van Cortlandt park, accord with this mode of retreat, and the slight but recognizable evidence which they bear of the presence of the ice along this eastern bank of the Hudson makes it reasonable to grant that the levels which they exhibit are those of local bodies of water held in position by the ice and hence subject to capricious changes.

Croton point stage. The strongest development of glacial deposits, such as are peculiar to the front of a retreating glacier, in the Hudson valley north of the great terminal moraine in Brooklyn and south of the Highlands, occurs at a point in the valley where there is again an important change in the geologic structure of the region. At Haverstraw, the thick sill of intrusive basalt which forms the palisades of the western bank of the river curves inland and westward, presenting its steep front to the north. At the same time the Hudson valley eroded in the Triassic basal beds widens out to the westward, and the gorge occupied by the existing river from Ossining (Sing Sing) northward bends around in deference to the geologic structure of its western bank. On the east bank there debouches just south of Croton point the Croton river, a curvilinear stream whose northward curvature may be compared with that of the trap ridge which touches the opposite shore at Haverstraw. We shall first consider the glacial conditions as they are found at Haverstraw, and then proceed to the interpretation of the deposits at Croton point and in its vicinity.

Haverstraw glacial deposits. The glacial deposits at Haverstraw from the base of High Tor northward along the shore and to Stony Point, for a mile or more inland, are rather complex, consisting of the more striking brick clays, glacial sands, gravels, and also till in the form of a frontal moraine. The extensive opening of the clay beds affords numerous opportunities for examining their structure and relations.

Frontal moraine. Once the ice front in its retreat lay north of the curved ridge of trap above referred to, any tendency to move southward would be met by the obstruction which this westward curving ridge offers, and as the ice, on the whole retreating,

had its times of slight advance, it is but natural to expect slight frontal deposits built against the northern slope of the Palisade ridge where its course turned so as to lie athwart the path of ice motion. Such deposits actually occur.

The morainal deposits of this stage are well shown at the Haverstraw station on the West Shore Railroad. The material is a reddish till in a thick deposit lying approximately between 100 and 200 feet above the sea from the vicinity of the railroad station to and beyond the limits of the Tarrytown atlas sheet. The conditions of the ice front at this time are indicated in the accompanying cross-section drawn across the front between High and Little Tor [fig. 8]. South of High Tor this morainal coating fails to appear as a flanking deposit on the iceward side of the trap ridge. As will be described in some detail presently,

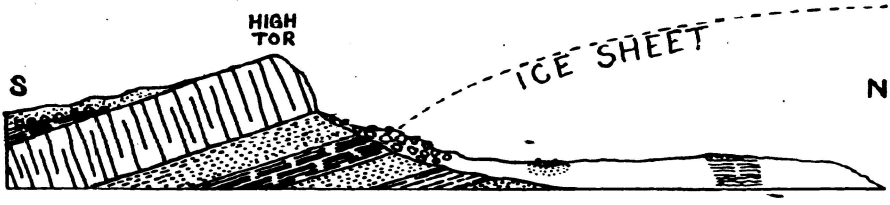


Fig. 8 Diagrammatic cross-section showing relation of ice sheet to frontal moraine at Haverstraw: below cliff, the moraine; to the right, clays, sands and gravels

morainal deposits reappear in the northern part of Croton point and it is therefore reasonable to suppose that the ice front left the west bank of the river in the vicinity of Short or Long Clove and crossed the Hudson gorge to the east bank, curving or projecting southward in mid-channel.

While the ice lay in the Hudson gorge south of Short and Long Clove, these two passes across the Palisade ridge would have afforded an outlet for the lateral drainage flowing between the ice on one side and the trap wall on the other. The long straight course of the Hackensack from the Cloves down to West Nyack is so well developed as to suggest that the stream may have been enlarged in the glacial period by water pouring through these passes, which lie at about 200 and 220 feet above the sea.

About $\frac{1}{8}$ of a mile south of the West Shore bridge over Minisceongo creek and east of the railroad there was a sand knoll exposed in 1900 in which stratified sands from 40 to 60

feet above the sea contained glacial boulders as if they had been dropped in from floating ice. Small lenses of gravel without pebbles of the trap or red sandstone betrayed their more northern origin than the area of Newark rocks. The upper layers of this section were much crumpled as if by overriding ice. The sands as a whole were yellowish and clayey. At one point a deposit of till lay in a shallow depression or channel in these sands.

The surface of this sand knob is clearly an erosion form. The crumpling of the upper layers, and the occurrence of patches of till show that it antedates the last local ice advance; yet the boulders dropped within it point to water at least 60 feet above the present sea level, during the deposit of the sand. But this water had nothing to do with the last glacial retreat.

The precise relations of these sands to the moraine at the base of the trap sheet is not shown by sections, but the evidence of ice action over the sands and the failure of sand deposits over the moraine, points evidently to the greater antiquity of the stratified deposits north of the moraine.

Cedar pond brook and its deposits. The clays in Haverstraw and North Haverstraw rise to about 50 feet above sea level though they are largely eroded away so that from place to place they rise to various hights below this level. In the northern part of Haverstraw between the 60 and 80 foot contours, the clays are overlain by about 10 feet of coarse gravels. South of the east and west road a pit in 1900 showed erosion of the clays before the deposition of the gravels.

Going farther north toward the valley of Cedar pond brook boulders appear in fences over the clays and also over a sand plain with foreset beds inclining to the southeast, showing the action of a stream pushing its delta out in this direction at a level as high as 60 or 80 feet above the present sea level.

Cedar pond brook has in recent times sunk its bed deeply and widely into its ancient delta the largest remnant of which forms the flat projecting point of land on which stands the village of North Haverstraw, at an elevation of about 100 feet above the sea.

This deposit evidently formerly extended farther south across what is now the path of the stream, thus uniting the coarser gravels and sands over the clays perhaps as far south as Benson's

Corner in a sheet of outwashed detritus, the position of which on the clays shows its more recent deposition. The precise age of these gravels and sands can be fixed in terms of the glacial retreat with precision, for the northern margin of the coarse detritus in the 100 foot plain at North Haverstraw shows clearly, by the ice contact slope of the terrace, that the deposits were along that line banked up against the edge of the glacier which still lay in the Hudson gorge. The age of the terraced remnants of the old delta is therefore fixed as nearly the same as that of the moraine at Haverstraw and earlier than all the various frontal deposits yet farther up the river in the line of retreat.

While the Cedar pond brook deposits are thus considered here as connected with the Croton point stage of the retreat it has to be recognized that the ice edge on the west side of the river had retreated from the moraine at Haverstraw station to the northern edge of the delta at North Haverstraw, a distance of 2 miles.

The clays underlying the Haverstraw gravels and sands are normal glacial deposits, evidently made in more or less open water the surface of which must have been at least 50 feet above the present sea level, but as the clays are overlain by the delta deposits made at the time the ice sheet pressed against the gravel bank at the North Haverstraw station, they can not be associated with deposits made at a later time when the river was freed of ice as far north as Albany. The precise age of the clays at Haverstraw is necessarily somewhat in doubt. North of the old delta with its ice contact at the North Haverstraw railroad station clays lie in the low grounds quite up to the south side of Stony Point. The clays rise up in the small hillock south of that point and evidently have there been much eroded. South of them rises the bluff of gravels in the North Haverstraw delta on which clays have not been deposited. Everything in this locality points to the conclusion that the clays are here older than the Cedar pond brook delta and that the ice sheet rested on these clays when the delta began to build. It is not so clear that the upper clays south of the Cedar pond brook were also in existence before the ice sheet retreated to the north shore of Cedar pond brook.

As previously shown on page 80 clays will begin to deposit along an ice front somewhat in advance of the sands and gravels

which the streams lay down along the ice margin and in contact with it. As the gravels and sands are dragged along and deposited further out, they will begin to cover the earlier deposited clays, and thus we shall have as the progressive steps in the deposition of a harmonic series of sediments the appearance in the lower and outer portion of the delta of an earlier set of clay beds and a later set of beds of gravel and sand. While the beds seen in any one vertical section are truly older at the bottom and newer at the top, the difference in age in this case is very slight.

Since the clays south of Cedar pond brook rise higher than those north of the head of the delta at North Haverstraw it is probable that the upper part represents the earlier clay deposits of this stage of delta building instead of some far earlier deposits like those seen near Stony Point. These clays will be found again in Croton point and further discussion of their origin may be deferred till that deposit has been described.

Croton point. On the east side of the Hudson, Croton point presents one of the most striking features of glacial origin in the course of the river from its source to the sea. There are larger and thicker deposits of drift but none which intrude themselves so forcibly on the plain map of the State. Croton point is again a complex of glacial deposits. The outer insular portion of this cape is partly of ice-laid morainal origin. All about the shores of Tellers point northward to the northern unnamed point the beach is lined with large glacial boulders. Dark boulders of a basic igneous rock are common and boulders of a red conglomerate undoubtedly from the Triassic strata underlying the Palisade range occur being derived probably from the basal strata of that formation in the bed of the river. On the western side of the north point the deposit of till with boulders and gravels rises high above the water level, showing that the ice front lay against this edge of the deposit, and as pointed out on page 99 that the ice front of the Haverstraw moraine crossed the river at this point, resting on the rocky shore of the eastern bank at Croton Landing where again thick deposits of till occur. The approximate position of the ice front at this stage is shown in the annexed sketch map [fig. 9].

In front of this ice edge Croton river appears to have entered into the Hudson much as it does now except at a higher level and to have deposited gravels near shore and sands farther out. At least some of these gravels and sands are preserved in the upper part of the Croton point deposit. The only question which arises is whether some of the material may not have been laid down by streams coming off from or out of the ice at this stage; but the occurrence of these plateaus of gravel and sand along

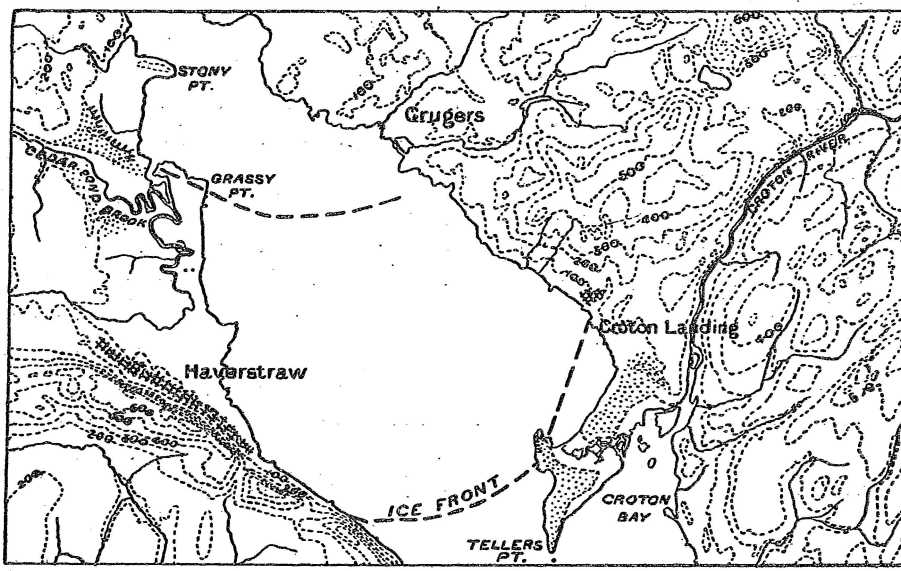


Fig. 9 Sketch map of the Croton-Haverstraw stage of ice retreat, with the later North Haverstraw stage

the ice margin at the points where streams now enter the Hudson both here and at the mouth of Cedar pond brook appears to be conclusive evidence that much of the work was done by lateral streams.

Again at Croton point as at Haverstraw the sand and gravel overlie a thick deposit of stratified blue glacial clays, which are well exposed in the pits along the north shore of the point.

Near the railroad on the north shore of Croton point about 20 feet above the beach, coarse glacial gravels with pebbles from

1 to 2 inches in diameter overlie the clays giving place above to glacial sands. At the northern point, there is reason to believe that the till is banked up against the clays if it does not overtop them. Probable evidence of the action of the ice sheet is found in the highly crumpled condition of many layers of clay; but this crumpling and contortion may have taken place as the result of the creeping of the clays when the overlying sands and gravels became thickly deposited on them. It is a characteristic of the outer clays in deltas.[1]

At the northern margin of the North Haverstraw dissected delta terrace and again at the northern extremity of Croton point there are slopes composed of coarse deposits coming directly from the ice sheet itself. These have been preserved as they were laid down, without erosion on the one hand or a covering of newer clays or silts on the other. They have suffered little from erosion because streams have run elsewhere doing their work most efficiently on the clayey deposits remote from the loose structured, gravelly beds near the ice contact. That these slopes have not been covered by newer deposits must be explained as in general due to their not lying in a basin of deposition. Either streams have not been directed toward them or if they have been submerged such submergence was very short indeed and the waters free from transported sediment. Indeed there has been no deposition above present sea level in this region since the ice retreated from the successive stages.

Cedar pond brook in cutting down through the North Haverstraw deposit has left a subordinate terrace at about 60 feet above the sea. This is a narrow terrace traversed by the road which leads southward from the village to the brook. The remnant of the old delta on the south side of the stream rises to 60 feet or over. The occurrence of a terrace at this hight made in the down cutting of the stream is suggestive of a water level at about 60 feet. The deposit at Tarrytown was built up to 60 feet above sea level. The full significance of these clues to a water level higher than that of the sea at present it is hoped to bring out in the discussion closing this report.

[1]Russell, I. C. Lakes of North America. 1895. p.50. Also in U. S. Geol. Sur. Monogr. XI. 1885. Ries, H. N. Y. State Mus. Bul. 12. 1895. p.108, 118–19.

The Croton point deposits like the North Haverstraw delta rise to about 100 feet above the sea level where they join the rock wall of the Hudson gorge. At Tellers point the gravels and sands fall off in hight to about 25 feet above the sea. Nowhere on this southern margin do there appear signs of glacial delta lobes. On the contrary there are marks of erosion, either that by the Croton river or by the action of the waves of Tappan sea.

The wide and deep cut across the point is clearly due to erosion following the deposition of the uppermost sands and is an essential part of the history of the changes in water level and the run of streams following the disappearance of the ice from the north side of this morainal stage. The outline of the cut, concave toward the northeast, describes the path which the present Croton river would in all probability take, were the Hudson flowing north instead of south as it now does. If the Croton cut this channel the process of doing so must have been at the beginning, by coursing over the deposit then more extensive to the southward and filling in the area between Croton point and the land known as Croton bay, the opening of which has given a more direct path southward into the Tappan Sea.

Against this view it must be said that the boulder deposits at Tellers point indicating the presence of the ice along the northern edge of the delta indicate also the possibility that streams poured out on that side from the ice and during the decaying stage of the ice front when a stream became free from its load, it may well have cut this channel quite down to the present level and that independently of the presence or action of the Croton river. The presence of creases across the surfaces of sand plains and deltas laid down along the ice margin is one of the striking features of many districts where the deposits were built partly above permanent water level.

Clays at Crugers. In the vicinity of Crugers a few clay pits have been opened in glacial brick clays closely resembling in all respects those on the opposite side of the river at Haverstraw. The clays have an eroded surface, rising to various levels up to nearly 100 feet. The deposits wrap about outcrops and occur in the hollows between the older rock topography of the side of the valley. Like those at Haverstraw the clays appear to have been deposited in the roughened and broken down rock terrace of the

Hudson gorge. At various places near Crugers glacial boulders repose on the clays and frequently in positions where it is impossible to suppose that they have slidden down from the slopes which overlook the clay deposits. This distribution of boulders is quite in accord with the evidence found on the west side of the river which points to the overriding of certain clays in this part of the Hudson valley by the ice at least in those stages of its retreat which are marked by moraines and frontal washed deposits in the vicinity of Haverstraw and Croton point. It is quite possible that each one of these frontal moraines and attendant outwashed deposits marked a slight advance of the ice remnant following a retreat somewhat farther up the river, and the mere overrunning of clays in this manner by the ice itself and the sheeting over them of gravels and sands contemporaneous with the retreating ice as a whole does not of itself demand that these clays be placed anterior to this last ice epoch. But the difference in the geologic position of these clays and those which still form broad plains about Albany and as far down the river as Kingston is sufficient to demonstrate that the clays in the Hudson valley south of the Highlands belong to an earlier stage in the melting of the great glacier than those from Kingston to Albany. In other words, the clays in the lower Hudson were laid down before the final disappearance of the glacier from this part of the valley; those south of the Mohawk from Albany down to Kingston are later than the disappearance of the ice from the region which they occupy.

There is thus no continuous deposit of glacial clays in the Hudson valley precisely equivalent in age to the marine beds of the Champlain area on the north.

Terraces about Peekskill bay. Well defined terraces of glacial gravels and sands occur in the vicinity of Peekskill bay at the southern edge of the Highlands; at Tomkins Cove and Jones Point on the west shore, and in Peekskill and Peekskill creek on the east shore. These deposits will now be briefly described in the order named.

Terrace at Tomkins Cove. The topographic map shows a narrow terrace developed on the side of the valley at Tomkins Cove. This terrace is delimited by the 120 and 140 foot contour lines and agrees very closely in level with the preglacial or inter-

glacial rock terrace of the Hudson river. No detailed study of it has yet been made in this survey.

Terrace at Jones Point. On the southern side of Dunderberg mountain at Jones Point or Caldwell there occurs a well defined terrace of sand and gravel of glacial origin, the original outlines of which have now been nearly destroyed in the course of excavation of sand and gravel for masons' supplies. This terrace extends along the mountain wall for about half a mile, being widest on the south where the mountain recedes from the river. On the north near Jones Point, the terrace springs out from the mountain side at an elevation of about 100 feet as a rather coarse cobbly gravel deposit and declines southward to about 60 feet of altitude. On the south it is separated from the mountain rock wall by a narrow gully which must either have been kept open during the period of deposition or have been excavated since by running water.

The slopes of the deposit are now altogether destroyed except for a small length of frontage near the northern end, but this portion of the bank is not very well defined—it may or may not have been filled in against a mass of ice lying in the river in the manner of terraces contemporaneous with glacial tongues filling a fiord or gorge. Its structure is more definitely shown.

The southern broad part of the deposit gave the following partial section in one pit from the top down:

	Feet
Fine loam with gravel	4
Gravel, egg sized	2
Sand	15
Gravel, very coarse	30+
Sand .....exposed	4

The face of a large opening at the southern end of the terrace in July 1900 showed the following instructive section [fig. 10], from which the mode of development of the terrace may be compared to that of the glacial deltas described on page 80.

The structure of the Jones Point terrace so far as revealed is that of a gravel bar building southward by the carriage of gravels over the surface of an embankment which must have begun to form where the terrace is tied on to the mountain side.

at or near its present northern end. These gravels coming to repose on the terminal slope under water formed successive inclined stratified additions to the deposit in this direction. The base of the deposit toward the southern end is sand and fine silt or rock-flour almost clayey in consistency. This finer material represents that which was washed off to the bottom at the foot of the growing embankment this being pushed out into the open water in that direction. These materials formed horizontal beds in front of the growing deltalike bar and were successively encroached on by the foot of each layer of inclined gravel and sand deposited on the growing slope of the bar. In this way origi-

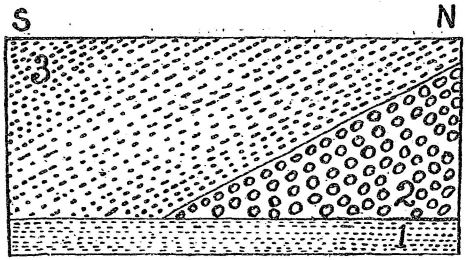


Fig 10. Section at southern end of Jones Point terrace in July 1900, showing at base horizontal beds of (1) sand, and rock-flour, overlain by southward inclined beds (dip 30°), of (2) coarse gravel with cobbles up to 6 inches, and (3) fine gravel up to 3 inches.

nated the unconformity at the base of the inclined beds. There was no erosion of the horizontal beds for they were in the deeper water with strong currents moving only near the surface.

The occurrence of coarse cobbles ranging up to 6 inches in diameter in these foreset beds nearly half a mile from the northern end of the embankment is evidence of strong currents running to the southward and on the concave shore of the present Hudson river where under existing conditions or with a higher water level it is difficult to conceive of a current of the river working at the level of this deposit being so directed as to produce the observed result. There appear to be but two possibilities concerning the circumstances of the formation of this terrace: either it was built by a strong southward flowing shore current during a time when the water level in this part of the valley stood about 100 feet higher than now or it was constructed in a glacial side channel at a time when the glacier filled the gorge in the Highlands and protruded southward as glaciers

now do in the fiords of Norway and West Greenland. The destruction of the slope of the terrace facing the river has removed the evidence which a former contact with an ice sheet or glacier would have left on the river margin of the deposit.

Terrace in Peekskill. The Hudson river winding through the Highlands approaches the southern edge of this broad northeast and southwest group of high ridges on a southeast course. No sooner is the river out of the mountains than its course bends sharply at first to the southwest then more nearly south. At the point where it escapes from the Highlands, Peekskill brook descending from the northeast finds its way into the main stream, making a small cove about a mile in length and $\frac{1}{3}$ mile wide deeply sunk into the old rock terrace. Between the city of Peekskill on the south and this creek or cove on the north stands a hill of rock rising to a little less than 400 feet. From the landing in Peekskill one may go around the southern and eastern sides of this hill into Peekskill brook valley by passing over a divide at about 170 feet. From the east a small brook now coursing through Peekskill falls into the Hudson at the southern base of this hill. On the southern slope immediately overlooking the river front at the southern end of a lofty ledge of bare rock which forms the western face of the hill is a glacial terrace with a delta structure. Well defined foreset beds below dip toward the river, and topset beds above incline very gently in the same direction. The surface of this deposit is at about 100 feet above the sea level. Its existence at this point indicates a stream carrying gravel and sand into the Hudson gorge along the south face of the hill. The deposit probably originally extended southward across the depression by which the little brook finds its way through the lower part of Peekskill, for on the south side of this valley there is a somewhat sloping terrace now at the same level occupied by residences.

There is no evidence clearly bearing on the relations of this deposit to the last remnant of ice in the Hudson river, for its river edge has been destroyed; but it is evidently a deposit made during this early stage of the ice retreat.

Peekskill creek terraces. In the valley of Peekskill creek, several deposits practically at the same level between 100 and 120 feet in elevation occur on the north and south banks of the cove,

and similar narrow terraces are not wanting farther from the main stream on Peekskill and Sprout brooks at gradually increasing hights above sea level. Those on the north side of the cove are best developed; and of these that forming the state camp is the broadest of all. I am not able to say how much it has been artificially graded. The slope of this terrace with its kamelike projections is quite unlike that of normal river-cut terraces on the one hand and lobate delta fronts on the other; the deposit appears to have been built in the presence of ice partially filling Peekskill creek. The same remark applies to the narrow terrace at the mouth of Annsville creek near the head of the same cove.

Roa Hook is an outlying rudely conical hill of glacial materials rising to the same level as the terraces in its vicinity. It has been opened for gravel and sand. On its top is a fine yellowish loam, from 3 to 5 feet thick; below this a dark coarse gravel bed, 10 to 15 feet thick, in which one large erratic was exposed in 1900; below which sands occur in the form of foreset beds dipping southeast, making a section about 30 feet thick. Near the railroad track sands occur dipping southeast at an angle of 15°. The gravels are locally cemented by carbonate of lime.

The dark shaly pebbles in these gravels are derived from the paleozoic rocks north of the Highlands in the Hudson valley. This northern source of the materials and the dip of the sand beds to the southeast show the direction of building of the deposit to have been downstream. The isolation of this deposit is hardly to be explained by the erosion of a once larger and more extended mass of glacial gravels and sands uniting all the terraces about Peekskill creek in a single deposit. The contours of the slopes or bluffs of these terraces as well as the untouched slopes of the Roa Hook mass preclude that idea; and the postulate of masses of ice partly filling the channel at this point and shrinking away from the rock walls here and there and so permitting the building up of deltas and terraces by lateral streams to a nearly common level meets all the requirements as regards the irregularity in outline and disposition of the various deposits.

A notable feature in the deposits of the vicinity of Peekskill is the complete absence of the superficial stratified glacial clays. Dr Ries has described clays rising about 4 feet above high tide level beneath the gravel and sand of the 20 foot terrace south of

Peekskill. These clays are probably an extension of the eroded ancient clays seen at Crugers.

Low level terraces. Again in this vicinity there are to be seen small areas of sandy plains stretching between rock outcrops in the dissected margin of the river gorge. One of these plains is well developed about the east shore of Lents cove, from a mile to a mile and a half south of Peekskill, with a surface about 20 feet above the sea. Another small deposit at about this level connects Roa Hook with the remnant of a rock terrace on the northwest of it. There is required much more evidence as to the nature of the original margins of these deposits on the river side before it can be asserted that they were or were not deposited in the presence of ice remaining in the gorge. They are evidently later than the high level terraces which overlook them.

Terraces about West Point and Cold Spring [*see* pl. 3, West Point quadrangle]. The topographic features of the Hudson at Peekskill are partly duplicated between 8 and 9 miles upstream within the Highlands in the vicinity of West Point. In this bend of the river, West Point with its terrace, takes the place of Jones Point, and Cold Spring on the delta of Foundry brook that of Peekskill. The ancient rock terrace of the Hudson partly masked by glacial deposits both at West Point and Cold Spring somewhat complicates the problem and gives the glacial deposits the appearance of a greater development than they really possess. It is interesting to note that Constitution island, a rocky mass in the middle of the gorge, is practically free of glacial deposits, for reasons which it is believed will appear when the bordering terraces have been discussed.

The West Point glacial terrace rises from 160 to 180 feet above the sea. The original character of the deposit is best shown north of the West Shore Railroad tunnel from the site of the cemetery to the weak morainal deposits at the base of Crow's Nest mountain. The upper deposits in this portion of the terrace are coarse cobbles becoming coarser and the deposit really bouldery near the base of the mountain named with a kettle moraine topography of weak relief. The railroad cuts north of the tunnel expose gravels quite to the river level showing that the deposit here is a true glacial terrace and not merely a coating of the ancient rock terrace as is the case near the parade

ground. There is here indubitable evidence of the deposition of the terrace in the presence of a tongue of ice lying in the Hudson gorge as Gilbert some years ago suggested.[1]

On the opposite side of the river below Cold Spring, a terrace of glacial gravels forms a counterpart to the terrace at the parade ground. It also, rests on and covers over the ancient rock bench at this point. Traces of the gravel of this stage exist in Cold Spring on the north bank of Foundry brook near the mills.

Gravelly water-laid drift also mantles the rock terrace both north and south of Highland Falls, and flattish deposits of the same character are not wanting on the rock terrace above Garrisons on the east bank of the river.

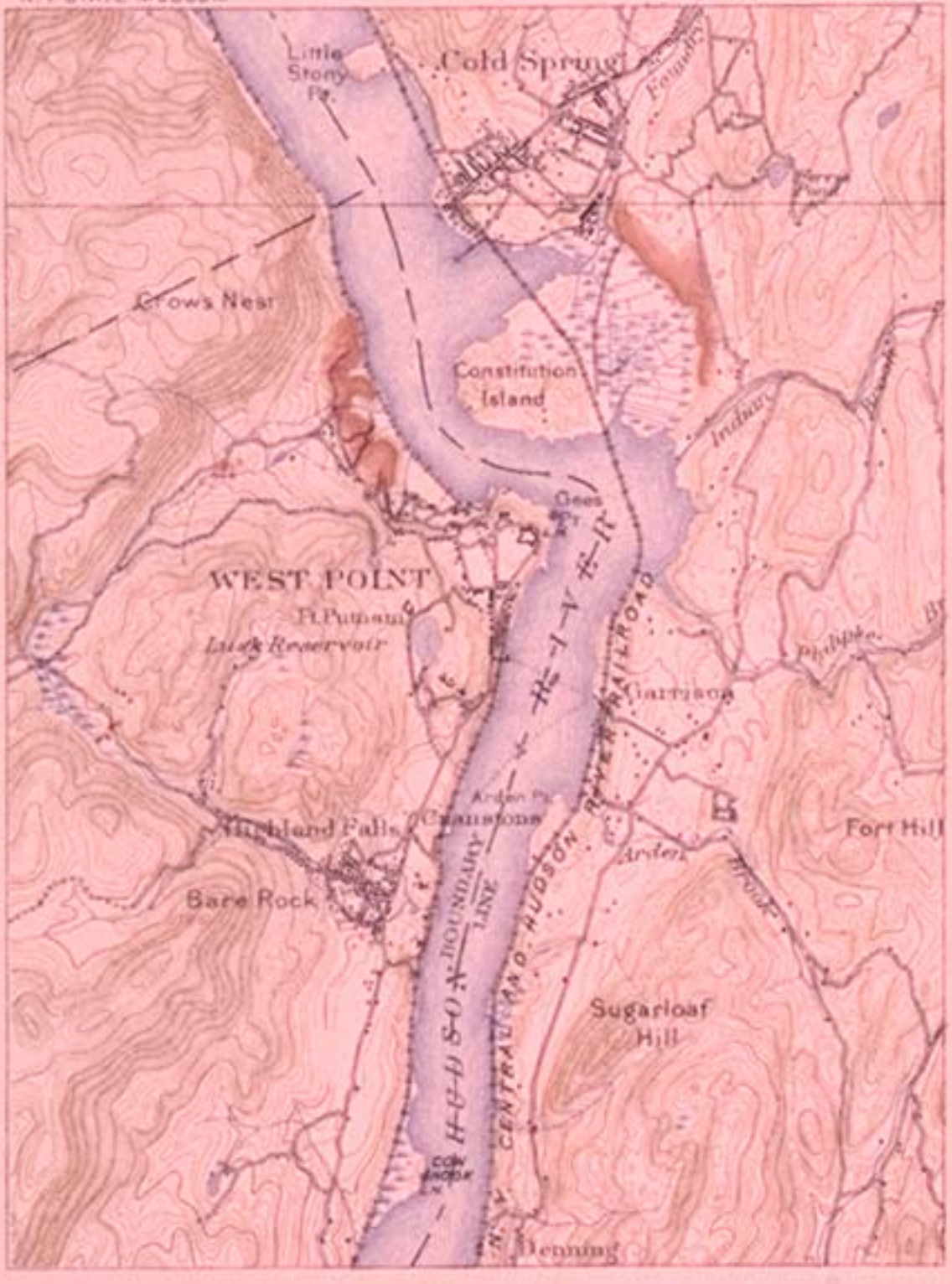
The West Point terrace is but the last and lowest of a series of deposits marking the dwindling away of the ice tongue which filled and pressed through the Highland canyon. Ascending the road passing from the soldiers quarters at West Point westward along the base of Crow's Nest mountain, one arrives within a distance of ½ mile at a small frontal moraine at an elevation of 400 feet. This deposit, mostly flat topped, is mounded on the east and though no section is shown it is probably composed in part of outwashed gravel and shoved or dumped materials coming from the ice sheet when the ice still rose to this hight in the valley.

Going westward to a junction with the Highland Falls road, then ½ mile southeast from the junction, this road traverses a distinct moraine forming a spur on the northern side of the valley. The deposit is convex downstream and is probably due to a lobelet of the ice pushed through this valley to this point prior to the halt at the 400 foot contour above West Point. These details are mentioned as showing the evidence of successive stages in the melting of the ice in the valley.

So far as the terraces at the West Point stage are concerned, their close approximation in level with the hight of the old rock terrace, the filling of spaces in the river bend upstream from the projection of the old rock terrace, and the thin veneer of the wash of this stage over the old rock terraces on both sides of the river suggest that the rock terrace controlled the hight of

[1]Cited by Dr F. J. H. Merrill, in Am. Jour. Sci. 1896. 41:461.

PART OF THE WEST POINT QUADRANGLE



DEPOSITS AT WEST POINT AND COLD SPRING.

Scale $\frac{1}{62500}$

1 0 1 2 Miles

Contour interval 20 feet.

Datum is mean sea level.

Glacial terraces.

Frontal moraine.

the terrace building by gravel-bearing streams. This evidence is stronger when it is noted that both rock terraces and glacial terraces are at this point in the river somewhat higher than at Peekskill. The elevation of the glacial terraces at Peekskill is from 100 to 120 feet; in the vicinity of West Point it is from 160 to 180 feet. Unless there has been a differential postglacial uplift of the axis of the Highlands, this difference of level of terraces at points about 9 miles apart, appears too great to be explained by the normal tilting of the continent on the supposition that the deposits were originally made at the same water level. If made, however, in ice-confined waters, their difference of level is expectable.

In the view of the terraces at West Point and Cold Spring having been laid down marginal to ice filling the channel in the

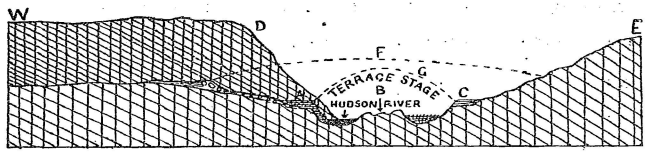


Fig. 11 Cross-section of the Hudson valley at the West Point stage. A, West Point terrace near cemetery; B, Constitution island; C, terrace south of Cold Spring; D, Crow's Nest mountain; F, ice at stage of the 400 foot moraine; G, ice at West Point terrace stage

manner of glaciers in the fiords of Norway, the lack of drift on Constitution island above referred to is at once explained, since it must have been at the time covered with ice, the cross-section of the gorge then being that shown in the annexed figure.

At Cold Spring on the south, facing Foundry cove, is a narrow terrace, rising about 40 feet above sea level.

Partial summary of preceding chapters. The front of the ice sheet retreating northward from the terminal moraine and up the Hudson valley halted temporarily at Tappan. The extension of the ice east and west of this locality is as yet imperfectly known. It certainly must have formed a broad sheet, rising on the north, over Little and High Tor, and filling the canyon of the Hudson in the Highlands if it did not also cover these last named elevations. Northward, the broad valley of the Hudson was still wrapped in the glacial sheet.

At Haverstraw and Croton, evidence exists of a temporary halt of the ice front, at a time when it had a rather marked convex

front as if spreading out on the lowland at the southern entrance to the Highland canyon. It is reasonable to suppose that at this stage the ice pressing against the northern slope of the Highlands and having thinned too much to flow over these ridges forced a long tongue through the Highlands comparable to the ice streams which are pressed out from the inland ice of Greenland to the west coast. With this stage some of the higher terraces and morainal deposits in the Highlands may be associated. Later the ice dwindled away melting at surface and also on its sides thus permitting the deposition of gravels and sands about its margins and over the rock terraces which at this stage bordered the dead ice in the gorge. With the melting out of this ice, the glacial occupation of the Lower Hudson was closed.

An earlier chapter in the glacial occupation of the lower Hudson valley is recorded in the terminal moraine and possibly also in the clays at Haverstraw which are covered unconformably by later sands and gravels. If the view be correct that the terminal moraine at the Narrows is the so called "inner" or Cape Cod moraine and that the "outer" or Nantucket moraine is to be found overrun by ice and suffused in the region immediately north of the Narrows it is probable that in the lower Hudson valley as on the east in Massachusetts the ice advanced some distance in taking up its position along both of these ice fronts. Considering these frontal moraines as respectively culminating the earlier and the later Wisconsin epoch, in the interval between the two episodes of southernmost prolongation of the ice front there would be opportunity for the deposition of some of the older clays which are found as far north as Haverstraw. On the other hand it must be recognized that the advance of an ice sheet causes it to overrun all deposits which have been laid down in front of it in its own time. It does not, therefore, from the evidence at hand, appear possible to conclude definitely whether the Haverstraw clays pertain to the latest Wisconsin or to an earlier epoch. That no clays are found in the lower Hudson overlying the deposits contemporaneous with the ice fronts in the Hudson valley, makes it evident at once that in this field none of the geographic conditions have prevailed which produced the widespread clays of the upper Hudson valley and the Lake Champlain district.

Chapter 3

GLACIAL DEPOSITS OF THE MIDDLE HUDSON VALLEY

North of the Highlands the glacial features of the Hudson take on a somewhat different aspect from those seen on the south. At Newburg and Fishkill glacial clays come to the river front in the form of terraces capped by sand and gravel, but gradually give way upstream to coarser and coarser stratified deposits, till at New Hamburg on the east bank glacial gravels appear like those near Peekskill. Thence northward to near Kingston point the glacial deposits bordering the river below the 200 foot contour are mainly ill defined deposits of gravelly till or rude kames such as are laid down where large masses of ice have melted out. The molding sands of this district are perhaps of a different origin. From Kingston northward to Albany and Troy there comes in a remarkable series of clay deposits which everywhere show by their surface being free of later drift and by their sharp incision by postglacial streams that they are distinctly later than the occupation of the valley by the glacier or its remnants and that they are, in fact, the most recent of the series of deposits which are to be associated with the disappearance of the ice. It remains to set forth what has been learned concerning the retreat of the ice sheet from the Hudson valley between the Highlands and the Mohawk north of Albany.

Cornwall terrace. On the west bank of the Hudson at the northern portal of the Highland canyon is the heavy deposit of gravel which constitutes the Cornwall terrace. The materials are very well shown in the cut bluff at the railroad station near the river. The materials all show signs of strong water action but not without the presence of ice. In the road up the hill from the railroad station a boulder 6 feet long was exposed at the time of my visit. The top of the terrace slopes toward the river and is covered with coarse drift. It is difficult to arrive at any satisfactory conclusion concerning the level of standing water at this stage from the remnant of the terrace. The surface as it exists may have been shaped above the level of the water in the Hudson gorge. The altitude of 170 feet is attained by the flat surface somewhat back from the brink of the bluff. On the

whole the deposit bears the closest analogy to the high terrace at West Point at the base of Crow's Nest mountain and occurs just where the waters ponded in the Walkill valley would escape along the ice border at the most favorable stage into the Hudson gorge. The much lower level of terraces on the north at Roseton and New Hamburg compels the belief that all the terraces in the Hudson gorge were deposited along the margin of a local protrusion of the glacier and thus lie above the level which standing water in the open gorge would have assumed at this time.

Northward near the mouth of the Moodna kill where the terrace still has an elevation of 160 feet there is a deposit of gravel and sand overlying stratified clays. The interesting terraces in this part of the kill are described on page 199.

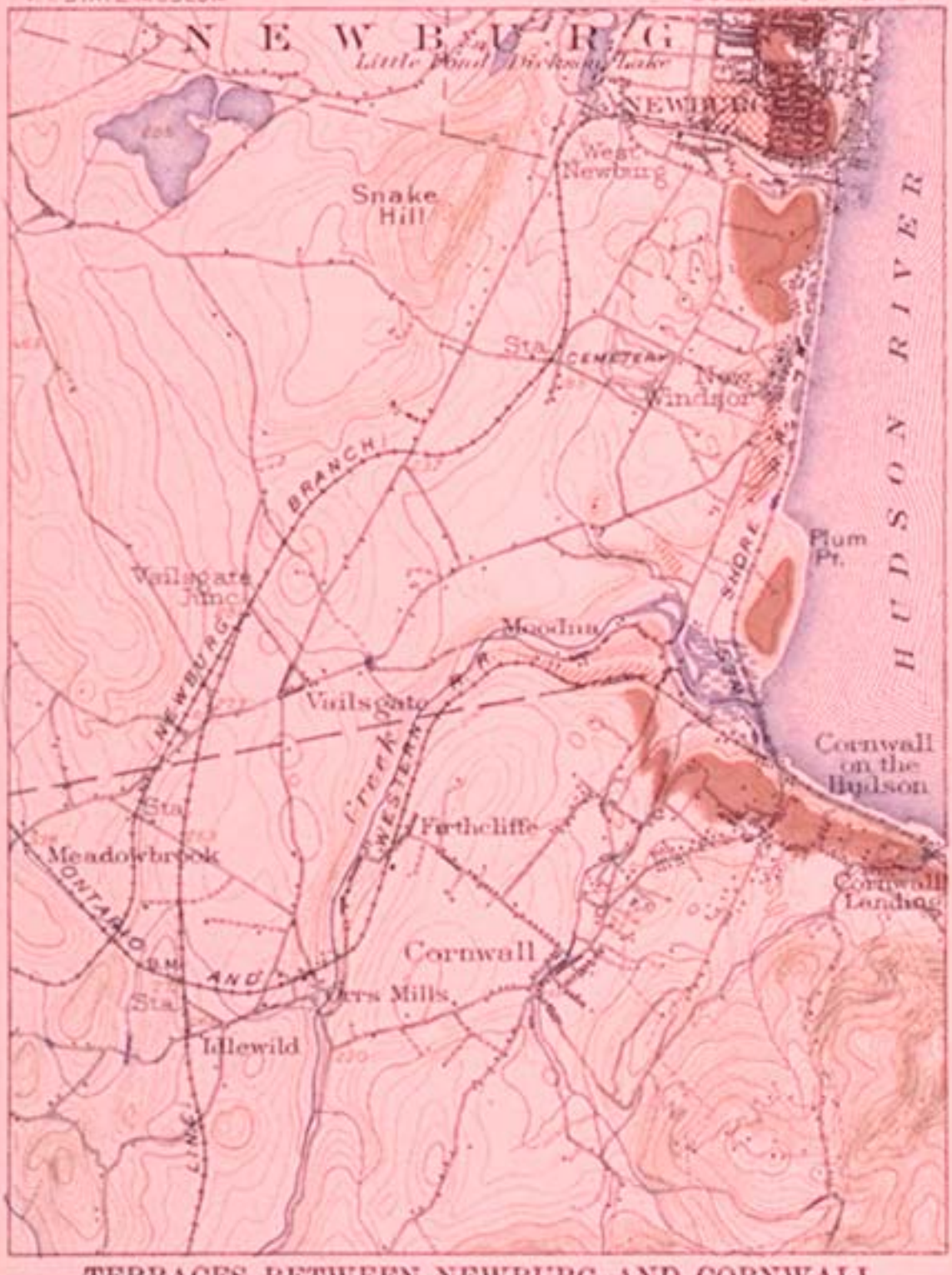
Newburg terrace. The city of Newburg on the west bank of the Hudson is built on a splendid terrace whose structure and consequently its glacial history are somewhat complex.

The terrace is most perfect on the northern bank of Quassaic creek where its elevation is about 150 feet. The front facing the river appears to have been eroded by the natural action of the river, though it is now largely artificial by reason of railway excavation and buildings which have been arranged along it.

Setting out from Washington's headquarters, the geologist proceeding southward traverses a depression leading to the river, beyond which he surmounts the best preserved portion of the terrace, which in an east and west section shows the profile given in the figure on p.117. In this section, the terrace presents the form of a glacial plain, deeply cut away on the outward or river side, and bounded on the west by topographic features which are distinctly due to the deposition of the materials in the presence of ice in the valley of Quassaic creek. The head or iceward margin of the plain is slightly mounded as if by the pressure of the ice, and the slope into the valley on the west is cast in the form of kames and mounds. In fact the country on the west and northwest as viewed from the terrace presents a field of kames drained by the Quassaic quite as distinctly contemporaneous with the ice sheet as those which have been described in the valleys of the Chenango and other streams.[1]

[1]Brigham, A. P. Glacial Flood Deposits in Chenango Valley. Geol. Soc. Am. Bul. 1897. 8:17–30.

PART OF THE NEWBURG QUADRANGLE



TERRACES BETWEEN NEWBURG AND CORNWALL

Scale 1/22500

1 0 1 2 Miles

Contour interval 20 feet

Datum is mean sea level

High level terrace deposits.

Ice-contact deposits.

100-foot Terrace.

60-foot Terrace.

The kame or ice contact slope of the terrace is strewn with angular stones up to 6 inches in diameter. A block of limestone lies in the morainal belt near the railroad, also ice-scratched pebbles and boulders up to 2 feet in diameter occur near the Bay View terrace.

The structure of the terrace shows that it is composed in part of clays and in part of sands and gravels. South of Washington's Headquarters Museum the clays appear to rise not higher than 30 feet above the river. Other points reveal a yellowish oxidized clay top in the plain with gravels in foreset beds beneath.

On the south side of Quassaic creek well defined foreset beds of gravel and sand form the principal part of the section down to

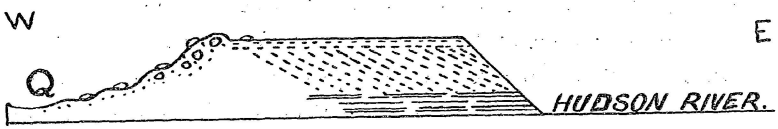


Fig. 12 Terrace at Newburg N. Y. Q, valley of Quassaic creek

the level of the West Shore Railroad tracks. These foreset beds dip eastward into the river gorge, showing that the terrace was built outward in that direction by the flow of water from the ice front lying back of the terrace [*see* fig. 12].

Another partial section on the north side of Quassaic creek, showed the following details.

LOCAL SECTION IN NEWBURG TERRACE

	Feet
Gravel, at surface	1
Sand	1
Clay, stratified	8
Sand, clayey	1.5
Gravel, fine shaly river pebbles	2
Clay above river	about 60

These clays near the railroad track dip gently east and appear to be locally eroded. This erosion is further evidenced by the manner in which they are replaced by gravels and sands with foreset beds south of Quassaic creek. The interstratification of sands and clays in the above partial section is instructive as showing that clay making went on evidently at this stage in close

proximity to the ice front. This is a particularly important conclusion in its bearing on the clays shown on the opposite side of the river at Fishkill Landing.

The clays at Fishkill and Dutchess Junction border on the river and are apparently free from overlying gravels and sands; but higher up at 140 to 160 feet are sandy terraces apparently referable to the Newburg stage. The details of glacial structure here require further study in the light of better sections than those exposed in the season of 1900. Enough is known however to show that after the ice front had withdrawn to the north side of the Highlands, it lay along the western side of the river at the back of the Newburg terrace while deposits of gravel, sand and clay were making in the Hudson gorge in front of it.

The southern end of the ice at this stage lay near West Newburg. Marginal kames occur between Newburg and Dickson lake. At the base of Snake hill there are morainal mounds curving eastward. At Windsor station one appears to be outside of the frontal moraine. An old overflow channel or crease is well shown ¼ mile southeast from the railroad station west of New Windsor. It runs through the southwestern part of a cemetery at an elevation of 140 feet. The channel is from 300 to 400 feet wide, cut in outwash sands which rise in the southern part of the cemetery to the hight of 160 feet, showing that while the ice still remained in this field the level of standing water in the neighboring river was much below that of the 160 foot terrace. Terraces made in the presence of ice are invariably above the level of standing water in the extraglacial region. From the facts at New Hamburg described below it would seem as if the water in the open Hudson gorge was at this stage not much above 100 feet higher than it now is.

North of Newburg the surface facing the river on that side has an eroded appearance, blending with the glaciated region of the western side of the valley. It suggests to the eye the occupation of this part of the valley by the ice while the Newburg terrace was forming; in other words, the ice front here approached and crossed the river. That it crossed the river somewhere between this locality and New Hamburg is shown by the decisive evidence as to the ice front at the latter place.

PART OF THE POUGHKEEPSIE QUADRANGLE



TERRACES ABOUT NEW HAMBURG.

Scale 62500

1 0 1 2 Miles

Contour interval 20 feet.

Datum is mean sea level.

Terraces.

Ice-contact.

Roseton terrace. This terrace is composed of coarse gravels dipping south in a cross-bedded structure. There are signs also of inthrusting of drift from ice movement [*see* pl. 5].

Danskammer terrace. The surface of the Danskammer terrace shows some erosion. It is capped with sand. The lower part of the terrace is blue clay. The elevation is about 90 feet. The strong contrast in the physical features of the Roseton and Danskammer terraces is rather typical of the abrupt horizontal changes met with in successive deposits seen within the gorge. The Roseton terrace can not be attributed to a river pouring into an estuary after the disappearance of the ice. It appears to have formed between the west wall of the river gorge and ice still lying in the district. The southern end of the Danskammer terrace immediately north of the Roseton deposit and at the same level points to more open conditions, and presumably is to be correlated with the outwash from the ice at the New Hamburg stage of the ice front [*see* pl. 5].

New Hamburg glacial deposits [*see* pl. 5]. From Newburg the gorge of the Hudson trends n. n. e. for 6 miles to New Hamburg on the east bank. Between these two points a few well defined terraces extremely localized occur as at Roseton and near Danskammer light on the west bank with surfaces between 80 and 100 feet above sea level. At Carthage Landing, a 20 foot terrace has a marked development.

At New Hamburg, Wappinger creek falls into the Hudson finding its way thereto through a considerable development of glacial gravels and sands which are well exposed in terraces about the pond at Wappinger falls and in the banks of the stream between that point and the Hudson river. At the village of New Hamburg these glacial gravels take on the form of a delta terrace deeply dissected by the Wappinger creek, and have a sharply marked ice contact slope on the western and northwestern margin of the deposit. The carriage road leading from the village northeastward to the top of the terrace has this ice contact slope on the right hand till the road surmounts the 100 foot contour line; thence the terrace is traceable along the river edge on the left hand, showing clearly that the ice front was at this point on the east side of the river probably crossing

to the west just above the mouth of Wappinger creek, and extending to the west of Newburg as above indicated.

It is worthy of remark here that the United States Coast Survey soundings of the bottom of the Hudson show a well marked ridge crossing the Hudson from the north side of Sherman's dock about 1 mile north of the steamboat landing at Newburg in a northeasterly direction to the east shore. Over this ridge the

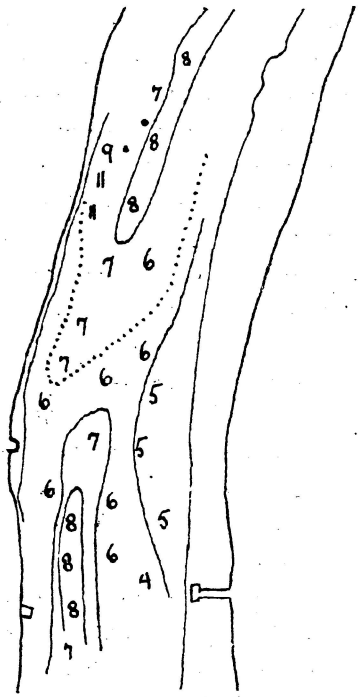


Fig. 13 Sketch map of the bed of the Hudson near Newburg N. Y., showing bar crossing the bottom of the Hudson. Figures indicate depth of water in fathoms. Constructed from United States Coast Survey chart no. 371

depth of water is 6 fathoms. North and south of this bar the channel falls off to depths of 7½ on the north and 8 fathoms on the south and these depths are maintained for several miles up and down the river. There is no reason for supposing that this bar is a normal feature of the development of the river, and it is explicable apparently on one of two hypotheses, either that it is due to a reef of rock less eroded than the rocks north and south by glacial action in the channel or that it is a deposit made

PART OF THE RHINEBECK QUADRANGLE



THE LATERAL GLACIAL TERRACE AT HYDE PARK

Scale 1/250

2 Miles

Contour interval 20 feet.

Datum is mean sea level.

Hyde Park terrace.

along the ice front at the time it crossed the river. The general form of the river bottom in this vicinity is shown in the sketch map, figure 13, in which contour lines have been introduced from the soundings given by the coast survey.

From this point northward, it seems best to trace out the ice front thus indicated on the east bank of the Hudson since it presents a series of glacial deposits essentially contemporaneous, after doing which the features of the Hudson gorge may be resumed from the same point of departure.

Ice edge of the Newburg stage north and east of New Hamburg. The reconnaissance made of the Hudson valley has sufficed to trace the eastern border of the ice mass which lay in the valley north and west of the Highlands nearly to Troy, though it is probable that the facts relied on for evidence on the north pertain to somewhat earlier and later positions of the ice than that shown at New Hamburg.

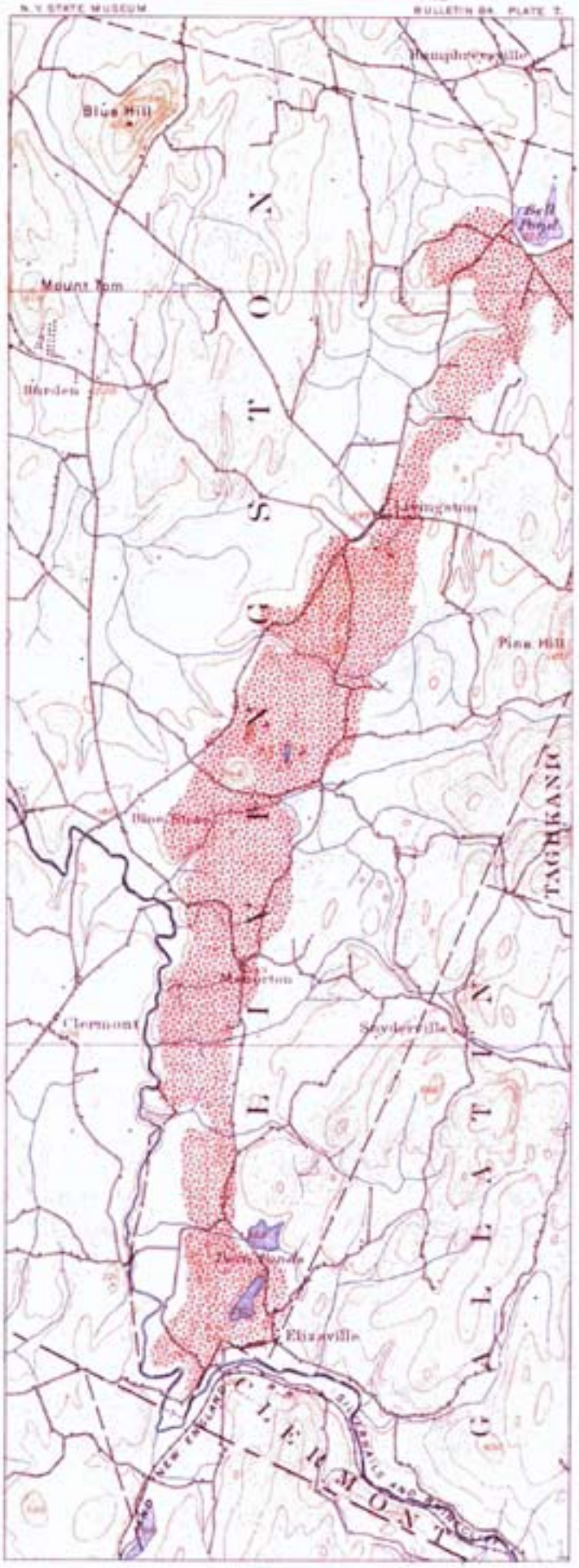
Lateral kame terraces. Between New Hamburg and Poughkeepsie [*see* pl. 6] there are terraces with kame kettles showing the site of remnant blocks of ice, and having steep ice contact slopes facing the Hudson river, the assemblage of structural and topographic features indicating that the ice overlay at this stage the eastern bank of the Hudson for distances varying from ½ a mile to about a mile as far north at least as Staatsburg. The kettle plains of this stage are well developed along Fallkill creek north of Poughkeepsie. Further traces of the ice border are found in the southeast corner of Red Hook township 1 mile northwest of Rock City at an elevation of about 320 feet. Further north in the southern corner of Livingston township the topographic map shows clearly the existence of another deposit along this line of ice front at an elevation of from 280 to 300 feet in the course of Roeliff Jansen kill. Going still further north, and at an increasing distance from the river, these kettle plains take on their most distinct and continuous development [*see* pl. 7] from near Bluestore to and beyond Livingston. A typical view of the belt may be had near the railway station at Elizaville. The ice contact slope has been locally cut back by the stream at this point. The terrace lies at a distance of from 5 to 6 miles east of the river, with its base ap-

proximately at the 200 foot contour line. The Roeliff Jansen kill appears to have discharged against the ice edge and contributed to the building of this remarkable deposit. The terrace is highest where the river now intersects it and declines in level northward. At Cokerville 2 miles south of the kill there is a fragment of the terrace which lies still higher. The question of the attitude of the surface of these deposits in relation to contemporaneous water levels and the precise attitude of the land at this stage has not been as yet investigated. Presumably the drainage along the margin of the ice at this time was southward.

According to the topography of the Kinderhook quadrangle by Mr C. C. Bassett, the Livingston lateral glacial deposits with kame kettles appear to be continued across this district at a slightly increasing distance away from the river as they are traced northward. The map shows a large ice block hole between Ghent and West Ghent at an elevation of 350 feet. Due north of this locality about 10 miles is a large ice block hole of irregular shape nearly 2 miles in length in which lies Kinderhook lake, with its water level at 288 feet. The surface of the neighboring plain at Niverville is 328 feet. South and east of this ice block hole are depressions indicating the deposition of the surrounding sediments in the presence of melting blocks of ice. Similar small kettles are shown along the Valatie kill north of Kinderhook lake, and they occur also northwest of this lake at elevations between 280 and 340 feet according to the map. I have interpreted these phenomena as indicating that the eastern border of the ice at the Newburg stage or approximately at that stage extended along the line of these kettles and that the marginal ice was suffused with drift washed in along the border. It also appears that the later Albany waters could not have deposited sand and clay so high as these kettles else the depressions would have been filled. Kinderhook lake is decisive on this point.

Schodack glacial terrace. The above described deposits are continued on the north in the deltalike terrace of the Moordener kill. The upper terrace between Schodack depot and Schodack Centre rises to the hight of about 340 feet on its outer margin overlooking the lower terrace about Albany. Its inner margin is about 360

PART OF THE CATSKILL QUADRANGLE



LEGEND

Kettle terrace.

The pits, some of them with lakelets, are the sites of buried or outlying blocks of the ice-sheet, surrounded by the wash of gravels and sands. At this time the region on the east of the terrace was free from the ice, but that on the west must have been covered by it. The low ground at the west base of the terrace was apparently invaded by the shallow waters of Lake Albany.

THE LIVINGSTON LATERAL MORAINE TERRACE

Formed on the eastern margin of the Hudson Valley ice-tongue

Scale 1/62500 1 Mile

Contour interval 20 feet

Datum is mean sea level

feet above the sea. The terrace has a distinct westward extension along the path now followed by the Moordener kill, and has the form of a delta built by this stream at this level but at a time when remnants of the ice sheet still filled the bottom of the Hudson valley in this region. The evidence of this lingering ice is found in several remarkable kettle holes bordering the stream and in the contour of the western front of the terrace which is strongly suggestive of an ice contact slope [*see* pl. 8].

The kettle holes in the delta are broad deep depressions with ice contact slopes having narrow gaps in each case on the side toward the stream. Two of these kettle holes are north of the stream, a large one forms a deep reentrant on the south bank. This last kettle hole is depressed below the rim of its outlet gap but contains no standing water because of the permeability of the gravels. North of the Moordener kill and south and west of the Schodack road, kettlelike depressions in the plain indicate the extension of the ice remnants in that direction. Yet another broad depression lies on the north side of Vlockie kill at the base of the hilly ground; and still another depression occurs to the south of this brook.

Moordener kill has partly dissected this high level delta terrace and sunk its bed on the rock at three points between 120 and 150 feet above the sea. The thickness of the deposit is evidently about 100 feet.

Northward the delta terrace is traceable as a narrow shelf of drift to and beyond East Greenwich, where on the west of the turnpiked road kettle holes again appear indicating deposition in the presence of masses of ice. Beyond this point, north of Mill creek, the terrace is not definitely traceable. Southward the terrace front retreats toward the hilly country and is not more than ½ a mile wide where traversed by Vlockie kill, and it extends south of this stream between the low till-covered hills to an apparent end at the southern limit of the Troy quadrangle.

The slope by which this terrace drops off to the level of the broader and smoother terrace adjacent to the Hudson river is singularly regular specially between Moordener kill and East Greenwich. At a few points along this slope the topography bears indubitable evidence of having been molded in the presence

of a glacier margin. The beachlike evenness of the contour of the base between the 260 and the 300 foot lines, the overlapping spitlike projection extending from the base of the upper or Schodack terrace southwestward on the north bank of the Moordener kill to Schodack Depot, as well as the character of the drift along this slope at the level named, are strongly suggestive of a water level between 260 and 280 feet. Between these two levels the bed rock is exposed in low ledges as if from the effects of wave stripping. The annexed diagrammatic section east and west in the latitude of Vierda kill illustrates the relation of the Schodack terrace to the lower terrace confronting the Hudson gorge.

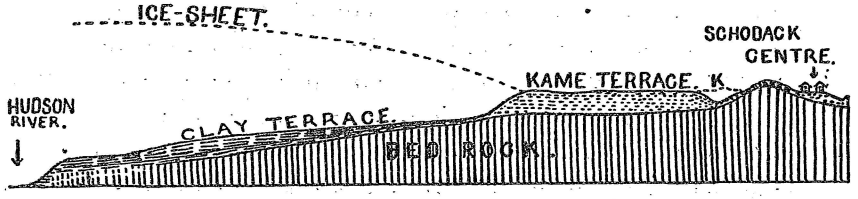
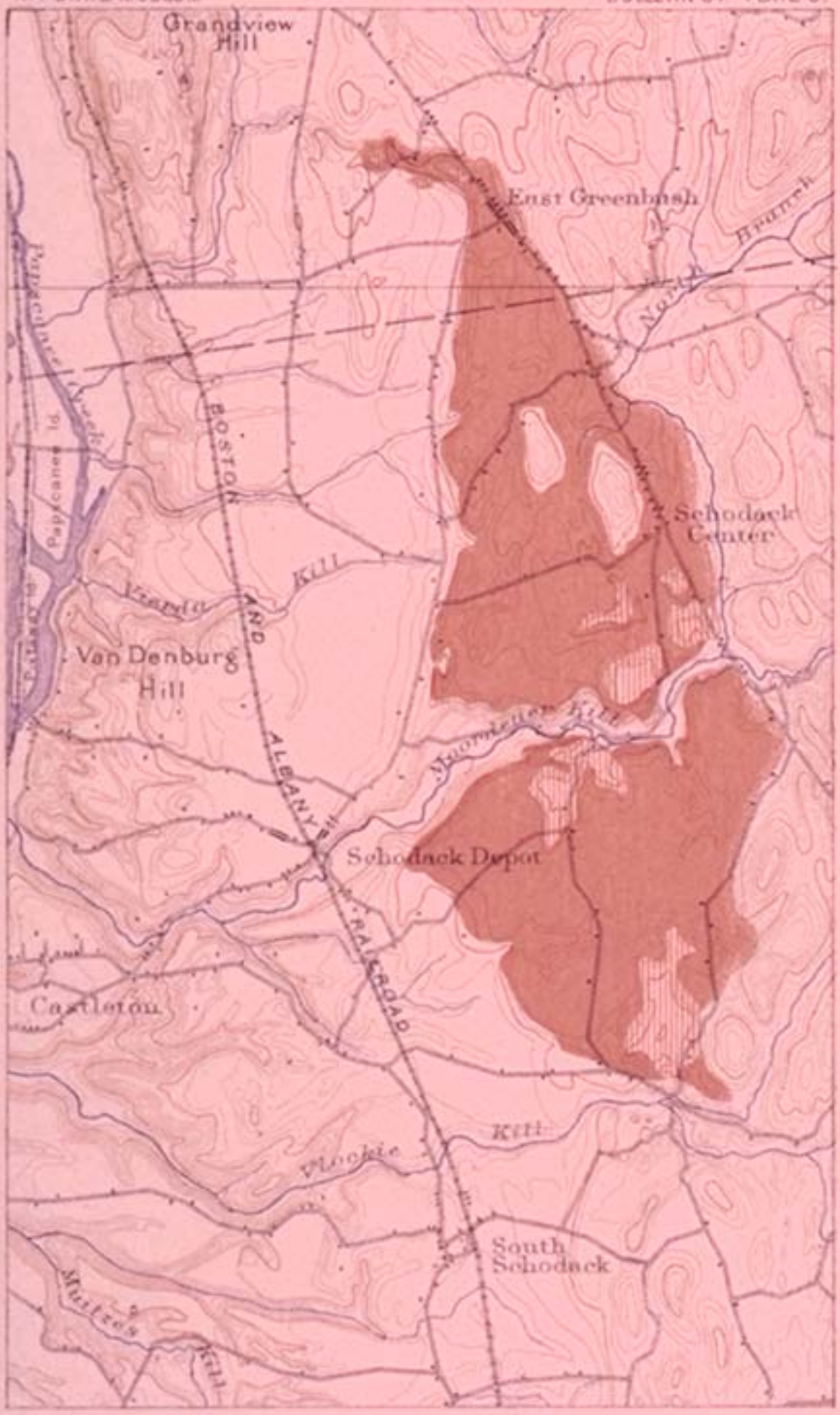


Fig. 14 Cross-section of delta terrace, near Vierda kill. K, kettle hole

South Bethlehem terrace. On the opposite or western side of the Hudson valley there is a small dissected terrace at the mouth of Oniskethau creek with its base resting on the old valley floor of the Hudson just west of the village of South Bethlehem. This terrace likewise rises abruptly from the low broad clay plain adjacent to the Hudson trench to the hight of 260 and 280 feet above the sea. The large remnant of the deposit on the south bank of the Oniskethau is totally unlike an ordinary delta built in an open water body. The outer margin overlooking the clay plain has a raised rim with a gentle slope for some rods back to the westward or upstream and the surface of the terrace is strewn with angular blocks many of which have now been gathered into fences. The long bar rising to the hight of 260 feet on the north bank of the stream is gravelly on its western slope but coated with till on the slope toward the valley in the manner of an ice contact. In fact, every feature of the outer slope of this terrace indicates that the deposit was made in a depression between the hills and the ice margin when the glacier filled the

PART OF THE TROY QUADRANGLE



THE SCHODACK LATERAL TERRACE

Scale 1/62500

1 mile 0 1 2 Miles

Contour interval 20 feet

Datum is mean sea level

Schodack terraces.

Kettle and Ice-block holes.

Hudson valley in the manner shown in the accompanying diagram [fig. 15].

It will be noted from the account which follows that these two terraces accord closely with the level of free deltas farther north. If these terraces were made in open water, it must have been during a temporary retreat of the ice tongue which lay in the valley, a readvance of which produced those aspects of the deposits as they now exist which point to deposition of the materials about their outer margins in the presence of ice. The limit of construction by water action in the South Bethlehem terrace was apparently a local affair. This appears evident from tracing this ice mass around the base of the hills bordering



Fig. 15 Cross-section of glacial deposit in Hudson valley from Schodack Depot to South Bethlehem, showing glacial terraces where the Moordener kill and Oniskethau creek mouthed on the ice border. The rock terrace is covered by clays of later deposition.

the west side of the Hudson valley past Feura Bush and New Scotland to the upper valley of Vly creek southwest of Voorheesville. In this region the escarpment of the west wall is indented by the New Salem valley drained by the creek named. When the ice retreated from the upland and its southern margin lay at this point, a barrier was created across the northward drainage of the Vly creek, holding up its waters in a temporary lake probably to the hight of the divide between it and the Oniskethau, about 430 feet above the present sea level. The west branch of Vly creek (see the Albany quadrangle) flows in a depression approximately along the line of the ice front at this stage. From the south bank of the creek, rises a terrace of glacial materials which attains an elevation of 400 feet, at a point west of the junction with the south branch of the same stream. This plain is a rude delta built into the lake at this stage. The outflow of this lake took place apparently through the Oniskethau and thence contributed somewhat to the terrace building at South Bethlehem. These trivial details have been presented as showing that deposits which are here indicative of

water deposition at levels 120 feet apart were presumably contemporaneous and made in the presence of ice-constrained waters above the level of the sea.

Kettle terraces of Sandlake and Poestenkill. From 7 to 12 miles north and east of the Schodack deposits and at a much higher elevation, the topographic map in the towns of Sutton and Jennings shows contemporaneous glacial terraces developed along the course of the Wynant kill and Newfoundland creek. The surfaces of these deposits are at various levels from 520 to 720 feet. They clearly pertain to an earlier ice margin than that nearer the river at Schodack and are far above the water planes of the valley subsequent to the disappearance of the ice sheet over the region south of Albany; but no examination of them has been made in the survey on which this report is based.

Having followed now from Newburg to the vicinity of Albany a series of deposits contemporaneous with the retreating ice sheet or tongue in the Hudson valley it is necessary to note other deposits in the same portion of the valley but nearer the river or in a doubtful relation to the ice sheet. These notes are concerned with a few typical cases only.

Arlington clay deposit near Poughkeepsie. South and east of Poughkeepsie as noted by Ries there are clays which are worked at Arlington with their surface at or about the 180-foot contour line. The precise stage to which this deposit belongs has not been definitely determined, but its position and association with the intraglacial debris which covers the terrace of the Hudson from the lateral terrace delta at New Hamburg northward shows that it is at least as old as the occupation of the valley by the Newburg ice remnant, but it may be an earlier body of clays. That the clays do not belong to the Albany stage is quite evident from the general distribution of glacial deposits in the vicinity.

Port Ewen deposits. Port Ewen lies on the south side of the mouth of Rondout creek. The terrace deposits here have an elevation of 150 feet, consisting of boulder clay below with striated stones, the blue clays and sand at top. The underlying till is very stony and gravelly, and may be seen in the bank as high as 30 feet

above sea level. Its contact with the overlying clays was nowhere well exposed at the time of my visit.

The top sands appear to follow the clays naturally as the result of shoaling water and the pushing out of the ancient delta of Rondout creek. It is noticeable that the sand beds have been cut out from time to time to the depth of 3 or 4 feet and as rapidly filled in by the continued transportation and deposition of sands from the same general source. The dominant cross-bedding in these sands displays a southeastward dip, but sections are exposed in which the opposite direction may be observed, from which it is to be inferred that the currents which carried the sand were subject to changes in direction. The almost complete absence of pebbles in this deposit is indicative of weak bottom currents at this level and as well the want of floating ice by which such coarse particles are often distributed.

Rondout terrace deposits. One sees two terrace levels about Rondout. A lower one is very well marked north of the ferry landing at about 50 feet above tide, the higher one occurs at 200 feet. A trench 4 feet deep in fine sand was exposed at the time of my visit at 51 Abruyn street near East Union street on the 50 foot terrace. This lower terrace is so much built over that its precise nature is in doubt. Toward the rock cliff and just north of the old cement quarry drifts, sand, composed in part of white quartz grains and hard shale bits, occurs as high as 100 feet and fragments of probably the same deposit rise to 120 feet.

Toward the north the 200 foot terrace shows gravel under the clayey sand of its upper section. So far as I was able to observe the clay is wanting in the immediate vicinity of the mouth of Rondout creek on the north; but at Kingston Point the clay appears and just south of the Terry hill triangulation station extensive clay banks have been opened.

In the Hutton Co.'s yard there is a topping of from 35 to 40 feet of sand, sometimes cross-bedded, with dip of cross-beds to the northeast. A lower part of this sand may fairly be described as clayey sand, pointing to a gradation into the purer clays beneath.

The clays are blue, with fine, white, micaceous sand bands varying in thickness from ¼ inch to 1 inch or even thicker. Thin

bands of the sand may be seen separated by layers of clay from 4 inches to 1 foot thick.

In the Terry bank, the top of the terrace is delimited by the 220 foot contour line. The clays have accumulated against a perpendicular wall of the limestone, and there is a topping of over 30 feet of sand. The clay bands in this bank are only about half as thick as those in the yard farther south and nearer Rondout creek.

The dominant southeastward dip of the cross-bedded sands on the south of Rondout creek at Port Ewen, and the northeast direction of the similar structures on the north of the mouth of that stream indicate the radial development of the clays and sands about Rondout through the discharge of the creek into a body of water whose surface was at least 200 feet above the present sea level at this locality.

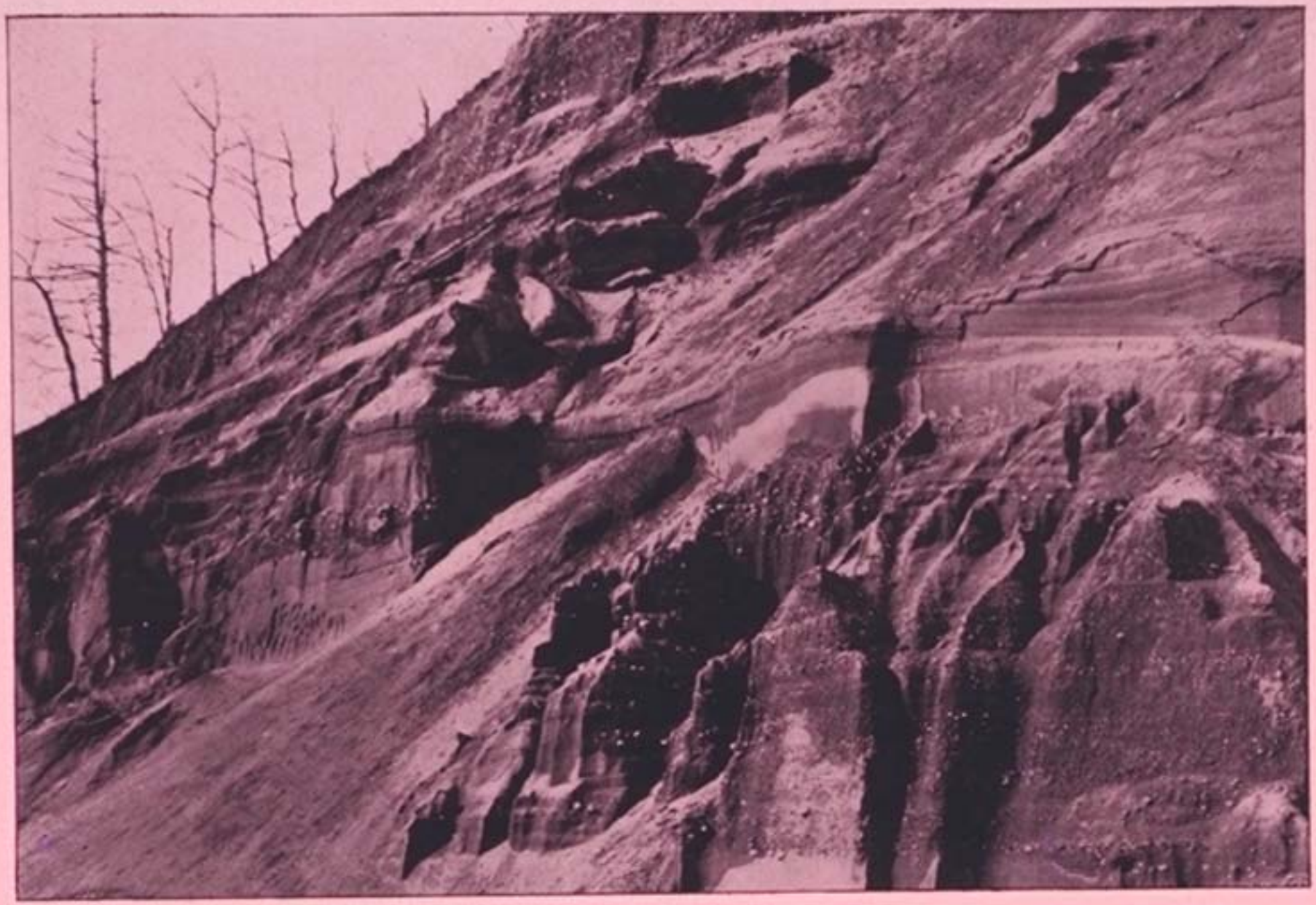
For several miles north and south of Kingston and Rondout the 200 foot contour line marks the break between the upper surface of the flats of clay, sand, or gravel which encompass the bases of the rocky ridges and lesser hills of bed rock.

Along the creek west of Kingston, gravels with coarse boulders rise above flood plain level. In a section 30 feet thick, a stratified gravel knob with boulderets up to 2 feet in diameter was seen capped by clays and sands, the summit of which did not rise above the 200 foot line. These coarse cobblestones are doubtless to be attributed to deposition by streams from the melting ice and therefore may be referred to an earlier epoch than that of the clays and sands.

We return now to the glacial deposits underlying the clays.

Meadowdale stage. About 1 mile south of Meadowdale on the western border of the Albany quadrangle there is a local morainal deposit with knobs and basins partly till and partly washed glacial drift the stratified components taking on a terraced form between the 280 and the 400 foot contour lines. Deposition evidently took place in the presence of the glacier immediately after the retreat of the ice from the New Salem lake barrier. This moraine or kame moraine merges eastward into a broad sand plain at about the 360 foot level. Kames and ridges of gravel outline its margin on the north. Across a depression on the east of it another small plain has developed at about the 240 foot

Plate 9



Stream-deposited glacial gravels and sands at North Albany; beneath the Albany clays

level. These three deposits are traversed by the road from Voorheesville to Meadowdale.

This falling off in the level of terrace and sand plain building from west to east, from 380 to 360 and then to 340 feet indicates a lowering of the water level dependent on the opening of lower gaps between the ice front and the escarpment on the east. These levels of construction so like the effects of ice-confined waters are within the zone of altitude affected by ice on the east bank of the Hudson in the Schodack district and lie above the broad clay plains immediately west and south of Albany and are thus clearly above any marine limit which has left a mark in this field.

At South Bethlehem the upper level of these Albany clays is 200 feet, near Voorheesville it is about 300 feet; in the dunes south of Schenectady the hight is about 360 feet, the precise elevation having been affected by the erosion and deposition of the fine sands by the action of winds in the postglacial epoch. The rate of fall from Voorheesville to South Bethlehem is about 1 foot to the mile for a distance of 10 miles, from the vicinity of Schenectady to Voorheesville a rate of somewhat less than 1 foot in a distance of 7 miles.

North Albany gravels. Between Albany and Loudonville on the north side of Patroons creek there is a high ridge of morainic aspect with long kettles and a boulder-strewn surface. These general characters are traceable northward beyond Ireland Corner. This deposit certainly antedates the Mohawk delta stage, and indicates by its form and structure that it was made during the occupation of the valley by ice, and is undoubtedly to be correlated with the lateral glacial terraces at Schodack and South Bethlehem or to a slightly later stage. The rise of the ridge to 360 feet or over in close accordance with the level of the Schodack terrace suggests that the remnant of the glacier in this district may have been sheeted over with flood plains of gravel, while the depressions were filled with the same material.

At the southeastern foot of this ridge in North Albany the clays are seen resting unconformably on these older glacial gravels. The gravels are locally very coarse and bouldery, layers of small boulders up to 1 foot and even 15 inches in diameter being seen well up in the section. The beds have a strong dip toward a depression on the north of this locality as if they had settled.

The relation of the clays to the older gravels shows that the gravels were cut off on the south by running water so as to form a well defined bank. Down this bank cobbles and boulders rolled. Subsequently clays began to deposit in horizontal layers against the bank, indicating a change from powerful streams of water running over the surface and cutting deeply into its drift deposits to a time of quiet silt-laden waters.

Further indications of the mode of building of these older gravels occur in a pit in the same vicinity. The structure is that of an aggraded deposit of gravels with extremely coarse lenses

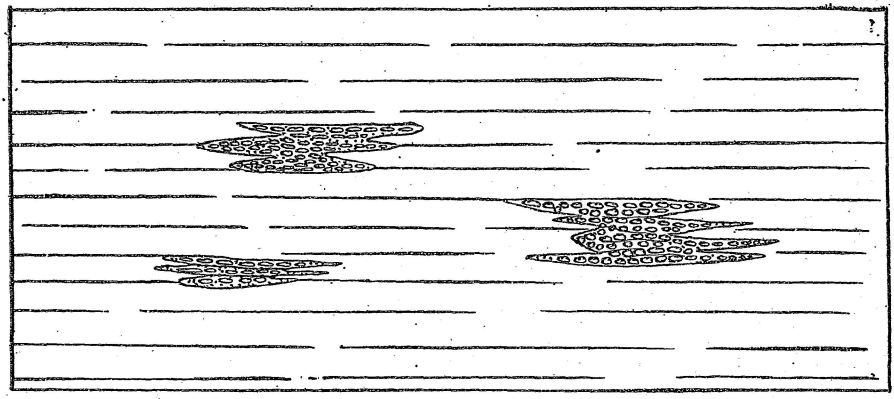


Fig. 16 Cross-section of aggraded glacial gravel deposit at North Albany, showing lenses of coarse gravel in old stream bed. [*See also* pl. 9]

showing where the stream bed as it wandered from point to point in the building up of the deposit happens to appear in the cut. The above figure illustrates the general cross-section of the pit.

Mohawk delta. The extensive sand and clay plains developed on the Albany and Schenectady quadrangles in the towns of Bethlehem, Guilderland, Watervliet, Niskayuna and Rotterdam, south of the Mohawk river, form an ancient delta of that river and are the most extensive deposits of this nature in the Hudson if not also in the Champlain valleys. The deposit, clayey below and near the Hudson gorge, gives way to sands toward the northwest and in the upper sections. Along the Hudson gorge the deposit fills in depressions in the rock bench and mantles this older topography except at such localities as the Abbey at Glenmont. The average elevation of the surface from Albany south-

ward at the brink of the gorge is now 200 feet. The surfaces rise northwestward to an elevation of about 350 feet near Schenectady. Between Schenectady and Albany the surface is mantled with extensive dunes of fine sand whose elevation rises to 400 feet, causing a postglacial elevation of the surface in this district by accumulation at the expense of the elevation of the deposit farther west near Schenectady. The Mohawk river now flows on the north of this delta. As will be noted in the account of the region north of the river the delta appears not to have been deposited in that district for the reason that it was covered by ice at the time the delta was building.

The present course of the Mohawk from Schenectady eastward is in a rock gorge separated, along the northern border of the town of Niskayuna, from the delta plain by till-covered ground rising above the delta level. At Alplaus[1] the Ballston channel extends to the north and east. The history of this network of drainage lines including the Ballston channel, and the Round lake drainage, has not been fully investigated. It seems clear however that the Mohawk delta began to make when the retreat of the ice sheet opened a passageway along the area covered by this deposit, and that the waters coming through the Mohawk valley pursued this course while the delta was building. At a later time when the ice melted away from the northern border of Niskayuna it left a tract at a lower level than the surface of the delta on the south and the river naturally began to flow along the course it now pursues below Schenectady.

It is difficult to fix any definite water level by the present elevation of the Mohawk delta. Certainly its lower clayey border near the Hudson river was under water during the stage of deposition. Presumably its upper stretches were not under water except in floods.

From a comparison of the neighboring evidences of shore lines indicated by small deltas and the upper limit of clays, I have hesitated to place the average water level above 320 feet.

Summary of the Newburg and related stages. Though the western border of the glacier which lay in the middle Hudson valley between Albany and Newburg has not been definitely

[1] This is the present corrupted spelling of the place originally called Aalplaatz—a good place for eels.

traced, the evidence on the east of the valley in the form of lateral moraine terraces shows that a long tongue of ice lay

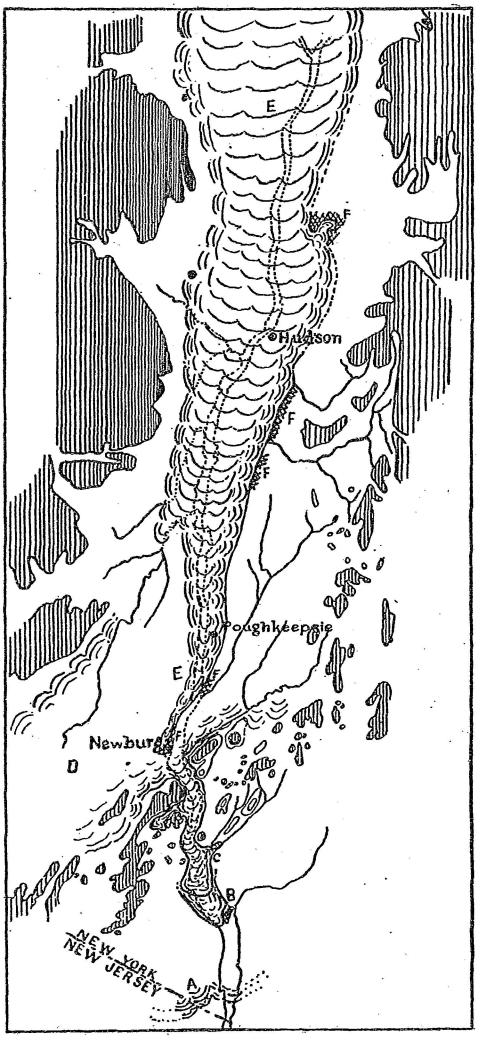


Fig. 17 Sketch map designed to show manner in which the glacier retreated in the Hudson valley. A, ice front at Tappan N. Y.; B, protrusion of glacier through the Highlands to Croton point; C, a later stage in the same; D, same stage as C when the ice still filled much of the lowland north and west of the Highlands; E, the Newburg stage. The western limits of the ice at the Newburg stage are conjectural. Definite margins of the ice on the eastern side are shown by ice contacts at F, F, F. Vertical ruling in areas over 1000 ft in elevation

over the gorge and for some miles east of the present river holding up the drainage of the side streams for a time, giving a more or less definite belt of deposits traceable northward as

far as the vicinity of Troy. The kettle holes in these terraces mark the sites of blocks of ice which melted out after the deposition ceased. Had the blocks melted out before deposition stopped the hollows thus formed would have been filled with gravel and sand. The deposits likewise serve to show that since the kettles took on their present shape the region in which they occur has not been subjected to sediment-bearing waters, and hence it is to be inferred that the lake stages which developed in front of the retreating ice sheet in the Hudson valley did not rise so high as these deposits. How long the buried ice remained after the withdrawal of the glacier from the terraces is not precisely known. But it does not appear likely that the ice remained in these positions during the subsequent lake stages whose duration as will be seen from the evidence here submitted must have been considerable.

North of Newburg the immediate banks of the Hudson exhibit stages of retreat of the ice in coarse gravels as near Staatsburg and Hudson with correlated finer deposits on the south of each such section, separated in many instances by banks of the old gorge in which till alone mantles the wall.

Where large streams enter the gorge as at Rondout, Kingston and Catskill there are also deltas with appropriate deposits. Clays are present in the southern part of the middle Hudson valley but they are subordinated to local deltas and to local stages of deposit in front of the retreating ice as is also the case throughout the river valley south of Newburg to the sea.

From somewhere near Kingston and Rhinebeck, clays begin to form a mantle along the rock terraces of the Hudson covering all the coarser deposits made in the gorge or over the immediate banks during the retreat of the ice from this vicinity northward to the Mohawk. This limitation of the clays was early recognized by Mather. The body of the clay is evidently to be correlated with the Mohawk delta and that with the discharge of a large body of water into the Hudson valley from Lake Iroquois on the west, a matter which is considered more in detail in a following chapter on Lake Albany.

Later stages of change in the valley are shown by low terraces partly within the gorge of the river and by the excavation which has taken place in that trench.

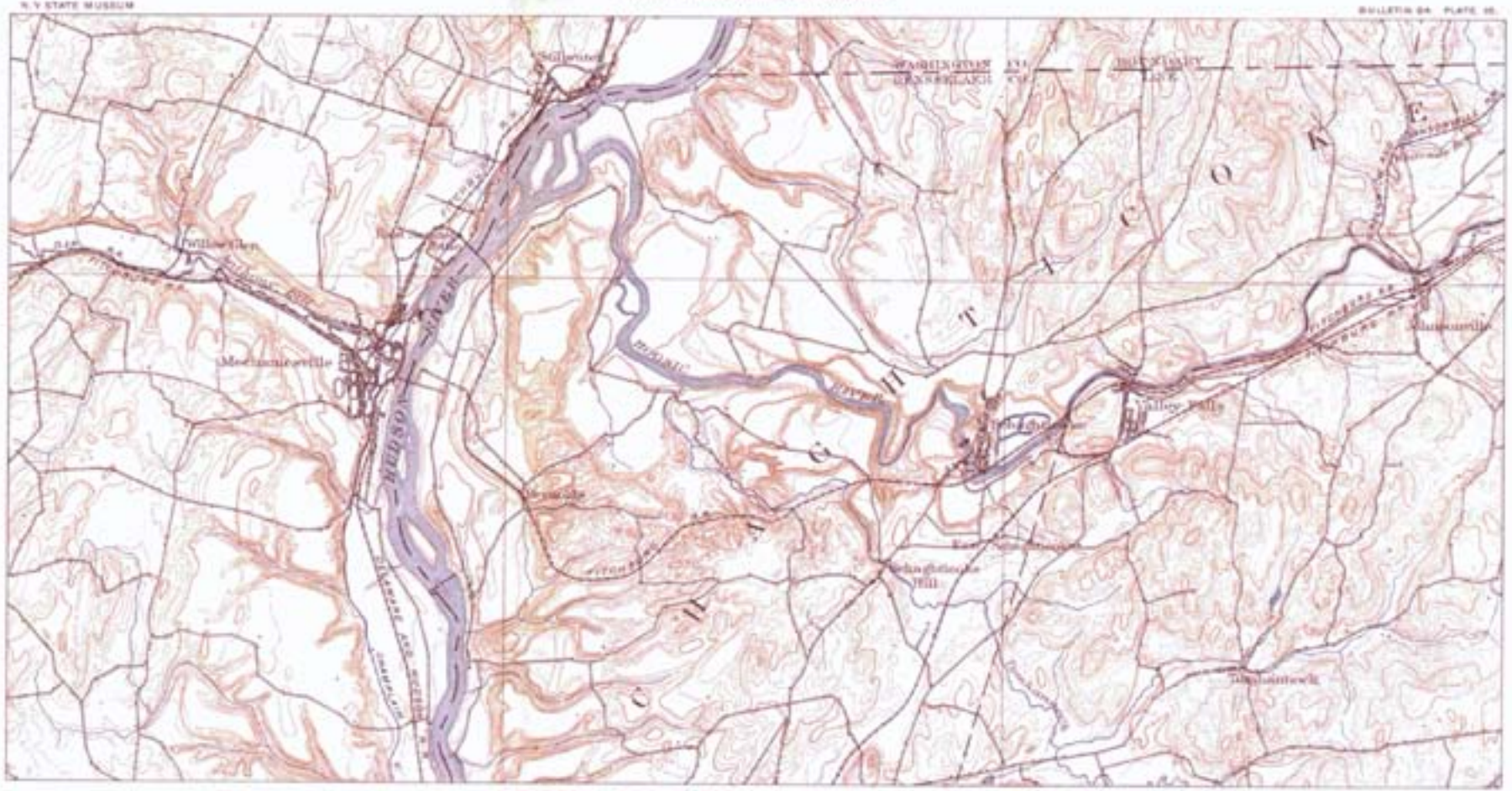
Chapter 4

GLACIAL DEPOSITS OF THE UPPER HUDSON VALLEY

From Albany northward the precise position of the ice front at its several successive stands in the retreat is frequently a matter of conjecture in the immediate vicinity of the Hudson gorge owing to the extensive water action which has followed the retreat of the ice from this district. In the following notes the geographic order is generally adopted as the basis of description. At many of the localities the deposits recorded and the topographic features noted pertain to widely separated events.

Hoosic delta. The Hoosic, the largest tributary of the Hudson river from the mountainous belt on the east, enters the Hudson gorge a few miles north of the mouth of the Mohawk and nearly opposite the Round lake channel at Mechanicville. The approximate apex of this delta is at Schaghticoke at an elevation of 360 feet. The Hoosic has sunk its bed deeply within the delta and the clays which border the Hudson gorge, turning to the northwest, a course which it has pursued since dissection began. There is a probable ancient temporary channel on the southeast border of the delta followed by a railroad between Melrose and East Schaghticoke stations. The bottom of this trench is about 350 feet above sea level. This rather marked deflection of the stream as it now runs to the north can not conclusively be stated to be due to the same cause as that which has been advanced for the position of the Mohawk on the northern side of its ancient delta. The dissection of the Hoosic delta is considered on page 200.

Above Schaghticoke with the falls in the stream there are two notable features: on the southeast the flats of Tomahawk creek extending nearly to Raymertown and on the northeast the glacial terraces bordering the Hoosic river to and beyond the limits of the Cohoes quadrangle. These terraces with an elevation of about 400 feet at Valley Falls, 4 miles farther east rise to 420 feet. They are sharply trenched by the Hoosic with lateral gullies. They are evidently flood plain deposits or parts of a valley train whose surface from Schaghticoke eastward lies above the level of the water body into which the river at one time discharged. Their levels have therefore been neglected in the consideration of the problem of water levels in the Hudson valley.



THE DELTA OF THE HOOSIC RIVER AND THE OUTLET OF ROUND LAKE (ANTHONY KILL).

Scale as here

Contour interval 20 feet.

Datum is mean sea level

Anthony Kill joins the Hudson through a trench cut in the Albany clays and drains an outlined depression on the west (see Plate I). The clay plains on either side of the Hudson, much dissected by streams, are characteristic features of the bottom of Lake Albany.

The delta of the Hoosic is largely clay and has been deeply dissected by streams (see Plate IV). The broken terrace of gravels on the north bank of the river from Valley Falls to the limit of the map is a remnant of the bed of the river formed after the freezing of the stream from the ice-sheet.

West bank of the Hudson between Schuylerville and Stillwater township. South of the valley of the Fish creek, the Hudson rock terrace extends back from the river as far as Quaker Springs with a width of about 2 miles. Clays or stony clays rise in flattish, stream-cut plains to the 300 foot contour line, where the Hudson slates meet the folded sandstone beds which form the belt of low hills on the east of Saratoga lake.

Southward toward the Stillwater line gravel and sand occur in beds as much as 10 feet thick over the clays. Near the river the sands suddenly cease, giving rise to a low terrace at the base of which small springs break out on the surface of the clays.

Farther north there are broad tracts in which the Hudson slates are practically bare of drift, such clays as appear at the surface being due to the disintegration and decomposition of the highly tilted slates. Over this eroded surface large, round concretions derived from the slates occur as boulders. Such concretions may be seen in place in the railroad cut north of Coveville and which when loosened from their bedding places might be mistaken for glacial erratics. These driftless strips near the river evidently demand the action of a strong current flowing through the Hudson valley apparently before the complete re-excavation of the gorge in its glacial and later clay filling [*see* p. 193].

Kendrick's hill. In the southeastern corner of Wilton township a hill, of at least glacial materials so far as the road cuts show, rises to three summits, forming a conspicuous object on the general level of the broad sand plains between the Hudson at Schuylerville and the base of the Adirondacks. About the northeastern slope the hill has a morainic aspect. In places it is enveloped with driven sand. I found no traces of shore lines on Kendrick's hill. In fact its base lies above the 320 foot contour line.

Saratoga lake region. Saratoga lake as in the case of Round lake occupies a depression in the bed rock but in this case of far greater extent than the area of the lake for much of the depression has been filled by glacial deposits. That the ice sheet is partly if not wholly responsible for the unfilled condition of this ancient basin is indicated by the form and distribution

of the sands and gravels and underlying clays in the flat topped glacial deposit which borders the west shore of the lake.

This deposit lies mostly between the 260 and 280 foot contour lines. Its steep sides have probably been cut back somewhat by the lake when the water was at a higher level and covered the low ground of Bog Meadow brook on the west.

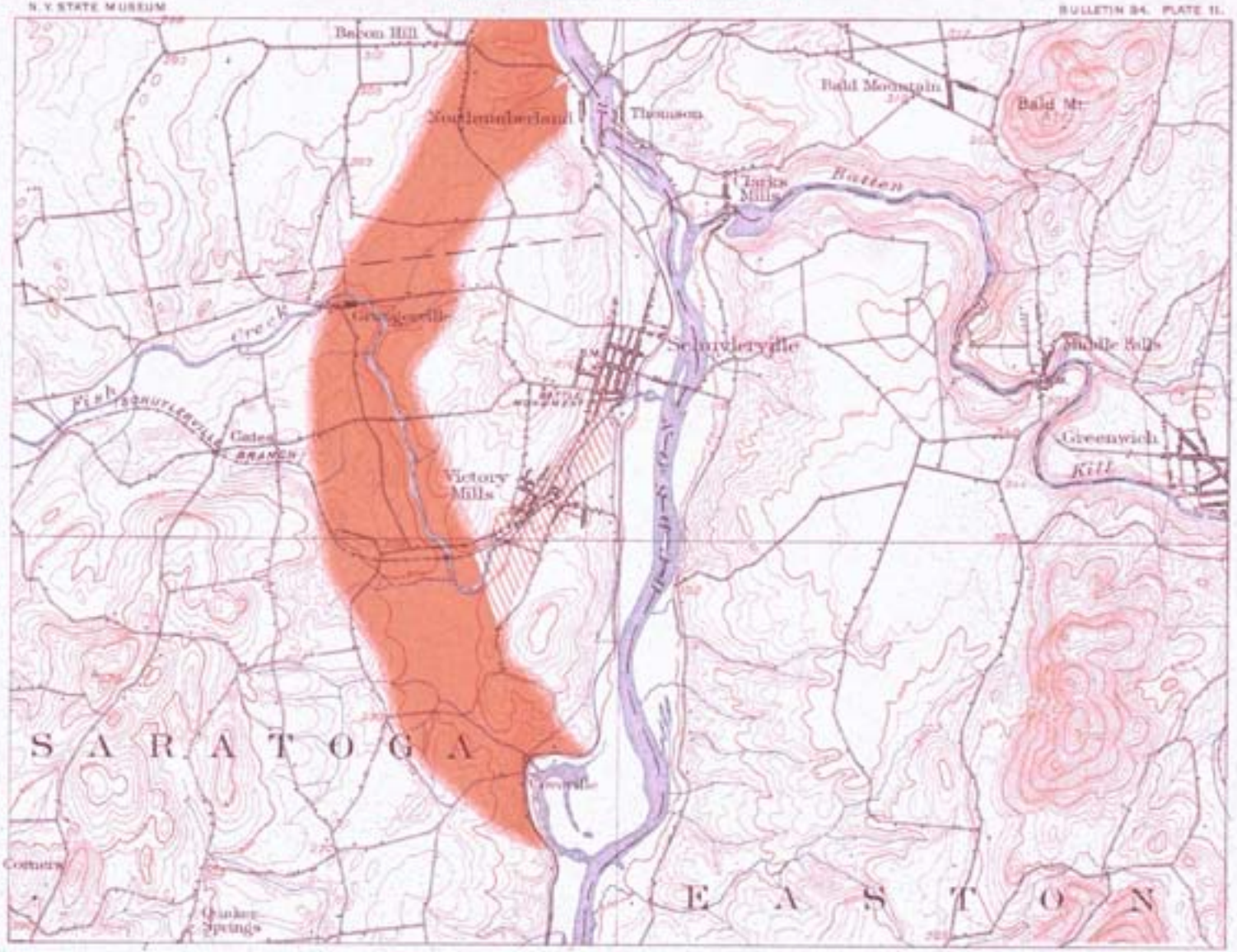
This 260 to 280 foot terrace is well marked in Fish creek valley. Extended gravel and sand plains of about the same level occur south of Saratoga Springs, the whole presenting a complex series of deltas apparently built in the presence of lingering blocks of ice. Till the detailed study of these deposits and their final mapping has been accomplished it will not be possible to state just what relations this area has to the Hudson trough on the east of it. It is evident though that the clays on the Hudson rock terraces were not abundantly deposited either in Fish creek valley or over the Saratoga lake district. This may have been because the lake region was so far from the mouths of clay-contributing streams and out of the drift of currents that clays were not brought to the district. There is no evidence of the clays having been swept out of the valley.

That clay-depositing waters occupied the region as high as the 300 foot contour line is shown by the character of the debris at the base of a cliff on the east bank of the lake 1 mile east of Saratoga lake station. Here the under, older part of the talus is grayish, clay-stained debris of the Hudson river rocks. Above and outside of this is a more modern talus of clean, black fragments of the cliff above, this newer talus accumulation being about 4 feet thick. It is to be assumed that the older talus at least as high as the 300 foot line accumulated in the waters which deposited clays at that level to the eastward on the Hudson rock terraces.

The ice remained longer over the depressions occupied by Saratoga and Round lakes than it did in the Hudson valley immediately east of this district. The large streams coming into the Hudson valley from the open ground on the east probably favored the melting of the glacier more rapidly on the side where their water coursed along the ice margin.

MIDDLE THIRD OF THE SCHUYLERVILLE QUADRANGLE

Showing a part of the region south of Plate 12



THE DELTA OF THE BATTEN KILL AND THE COVEVILLE CHANNEL.

Before the Coveville outlet was used by the discharge from Lake Vermont, a powerful current swept southward over the west bank of the Hudson near Quaker Springs. The Hudson gorge in this area was still filled with drift and clays.

Scale 4 miles

Contour interval 20 feet

Datum is mean sea level.

The delta of the Batten kill, now dissected by the stream, forms the plains about Bald mountain and southwest of Greenwich. The delta originally extended across the Hudson gorge as far as the Battlement monument.

Coveville outlet.

Former buried valley

The precise boundaries of the retreating ice sheet are obscured by the abundant deposits of sand and clay and by the further blowing of the sands by winds in the district between Saratoga and Gansevoort, so that in spite of several days spent in the endeavor to trace the limits of retreating masses of ice I was unable to get a satisfactory idea of the precise alinement of the ice front across the valley in this field.

Delta of the Batten kill [*see* pl. 11]. The Batten kill debouches into the Hudson river at Schuylerville near the northern limit of the main body of the Albany clays. A broad delta of gravels and sands caps the clays on the east bank of the Hudson stretching back from the gorge to the low range of hills which forms the eastern border of the Hudson valley. The Batten kill passes westward through this range at Greenwich where the terraced apex of the delta rises between 340 and 360 feet. Along the western base of the hills the delta extends south of the stream as a broad plain for nearly 2 miles. Three points leveled on the inner upper margin of the deposit near the river are according to the state map at elevations of 348, 344, and 358 feet respectively, from which 350 feet may be taken as the approximate upper level of the delta. Outward the delta falls off to the 320 foot line with a very gentle slope and then descends more rapidly to the 300 foot level. North of the stream at the base of Bald mountain a considerable stretch of the delta plain lies between 300 and 316 feet above the present sea level. Since the outer margin of the delta where it falls off most rapidly is a better index of water level than the apical portion of the deposit merging into the flood plain level which was probably built above water level, it appears that the water level at this point is approximately 320 feet above sea level. Southward of the delta the clays and sands meet the base of the hills at about the same hight.

Northwest from Bald mountain and between the 300 foot level and the river lies a lower plain whose surface is between the 220 and the 240 foot contour lines, a level which is well marked at several places on either side of the Hudson gorge for 5 or 6 miles north and south of Schuylerville, but one which is very close to that of broad areas of the bed rock in the immediate

vicinity of the river. A broad shelf at this level borders the Moses kill where that stream enters the Hudson gorge. In such cases the drift deposit may well depend on the bed rock for its position.

The erosion forms of the Batten kill delta along the bank of the Hudson opposite Schuylerville form a conspicuous feature in the landscape and the topography of this side of the river is in strong contrast to the west bank on which the delta sands appear in the vicinity of the Saratoga Battle Monument.

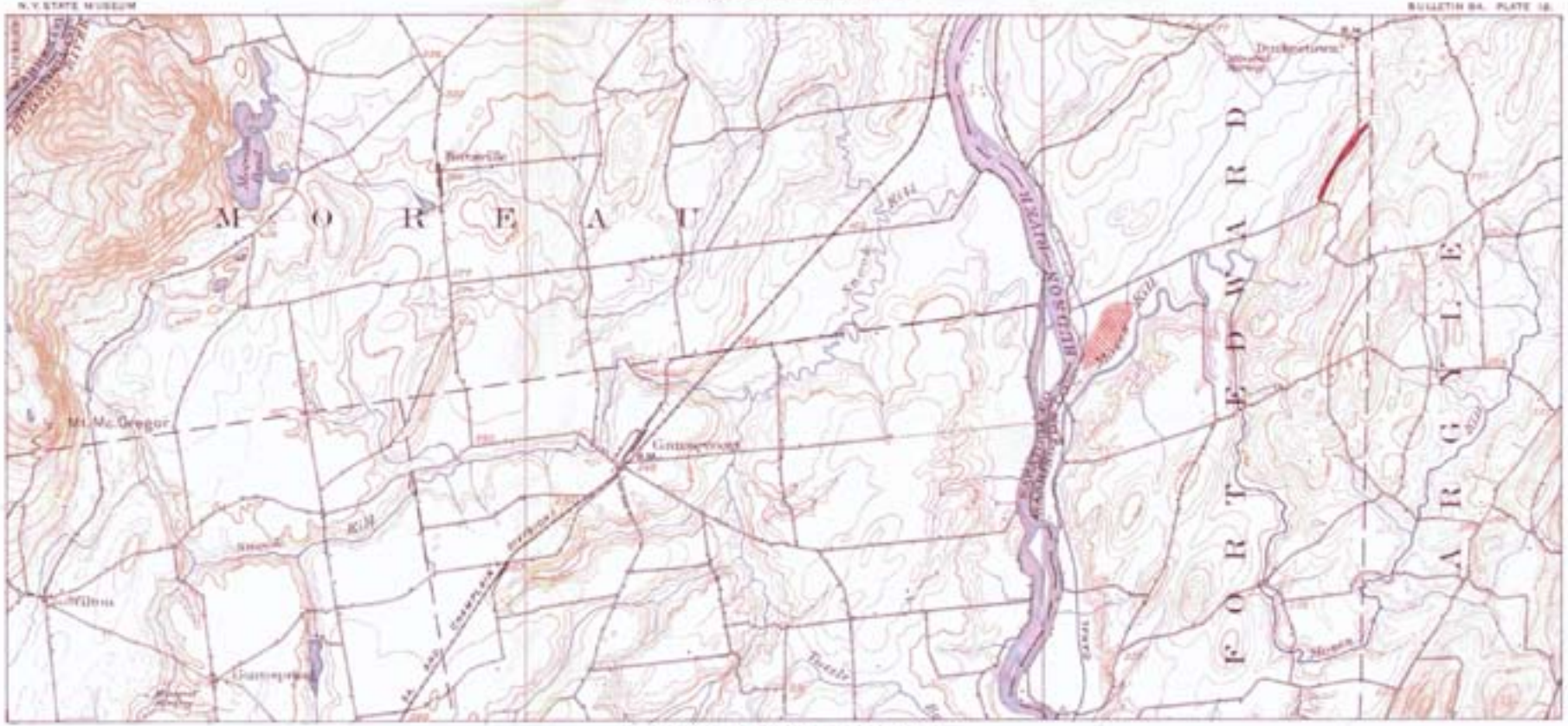
The clays which underlie the delta appear throughout the district below the 300 foot level.

Durkeetown terrace [*see* pl. 12]. One mile south of Durkeetown in the northeastern corner of the Schuylerville quadrangle a ridge rising above the 300 foot contour line extends south-southwestward for 1½ miles, bounding the Fort Edward district on the southeast. On the western slope of this ridge between the 280 and 300 foot lines is a weakly developed terrace of water-worn gravels. These are coarse cobbles on the northeast above the road but become fine gravels toward the southwest at the crossroads. The general appearance of the deposit is that of a beach on which the materials have traveled southwestward. There is nothing in the frontal slope of the narrow terrace to prove that the margin of the ice remnant lying over the Fort Edward district confined the deposits as in the case of many likewise narrow terraces at higher levels along the base of the mountain on the west of the same district. The terrace may be taken therefore as the index of water level during the closing stages of the deposits of the Albany clays when the ice had melted out at least as far north as this locality. On the east of the same ridge is a flat floored valley at about the same level, one which corresponds with the upper limit of the clays over the western part of the Fort Ann sheet on the north and with the outward margin of the delta of the Mettawee at West Granville.

Fort Edward district. At the northern border of the Schuylerville quadrangle the rock terraces of the Hudson gorge retreat east and west, and the gorge widens out into a depression traversed by the present but newly established course of the Hud-

NORTHERN THIRD OF THE SCHUYLERVILLE QUADRANGLE

Showing the Hudson Valley south of the district mapped on Plate 13, and north of that on Plate 11



THE REGION ABOUT GANSEVOORT.

The lakes and depressions, of which Moreau pond is the largest, are due to the melting out of ice blocks. This region was above the level of standing water on the east and south. The flat plains about Gansevoort are the remnants of a great plain of sands and clays forming a delta under the water level T—U of Plate 25.

Scale 1 0 1 2 3 4 5 Miles

Contour-interval 20 feet.

Datum is mean sea level.

Terrace or beach (?).

Water-worn rocks.

This map shows the Dunnsville outlet of Lake Vermont and the traces of the higher water levels controlled by the outlets on the middle third of the Schuylerville quadrangle (Plate 11).

son from the base of the Adirondacks to Fort Edward and by the older channel of Wood creek. It will be convenient to treat of the glacial features of this district in what appears to be the order of their sequence in time which as everywhere in the Hudson valley is quite uniformly in a descending order as regards the vertical distribution of the deposits. These deposits consist of high level terraces with invariably an ice contact face confronting the Fort Edward district, and a lower series of deposits made in open water; while at still lower levels there is the evidence of erosion by running water as in the gorge farther south.

Of the glacial terraces, the highest and oldest as well, lies within the Adirondack canyon of the Hudson. This deposit rises to the

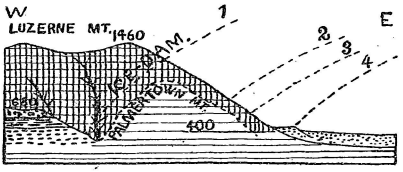


Fig. 18 Terraces in the vicinity of Palmertown mountain. On left hand is shown the Hartman terrace in the Hudson canyon. 1, 2, 3, 4, represent successive positions of retreating ice margin. At 4, is the kame terrace at eastern base of the mountain overlooking the Fort Edward district.

hight of 680 feet above the sea or about 400 feet above the bed of the river at its base. The small hamlet of Hartman post-office is located on its top. The river has cut away the eastern front of the deposit giving a partial exposure of coarse gravels about 200 feet thick at base, over which come stratified clays and sands, above which in turn occur gravels with a rude kame topography, the whole showing a time of torrential currents in the canyon followed by lacustrine conditions with the deposition of clay in the gorge to a hight fully 500 feet above the present sea level; then a return of the ice in the coarse glacial detritus which caps the clays. The entire series is evidently earlier than the deposits which occur outside of the mountainous belt over the Fort Edward district and therefore need not be taken further into account in an attempt to fix the water levels which followed the disappearance of the ice from this region.

The glacial terraces which flank the mountain bases around Fort Edward are typically represented in that of Palmertown

mountain, a lower level about Glen Lake, a higher one at Patten's Mills on the north, and those of till at North Argyle and Evansville, which will now be described in the order named.

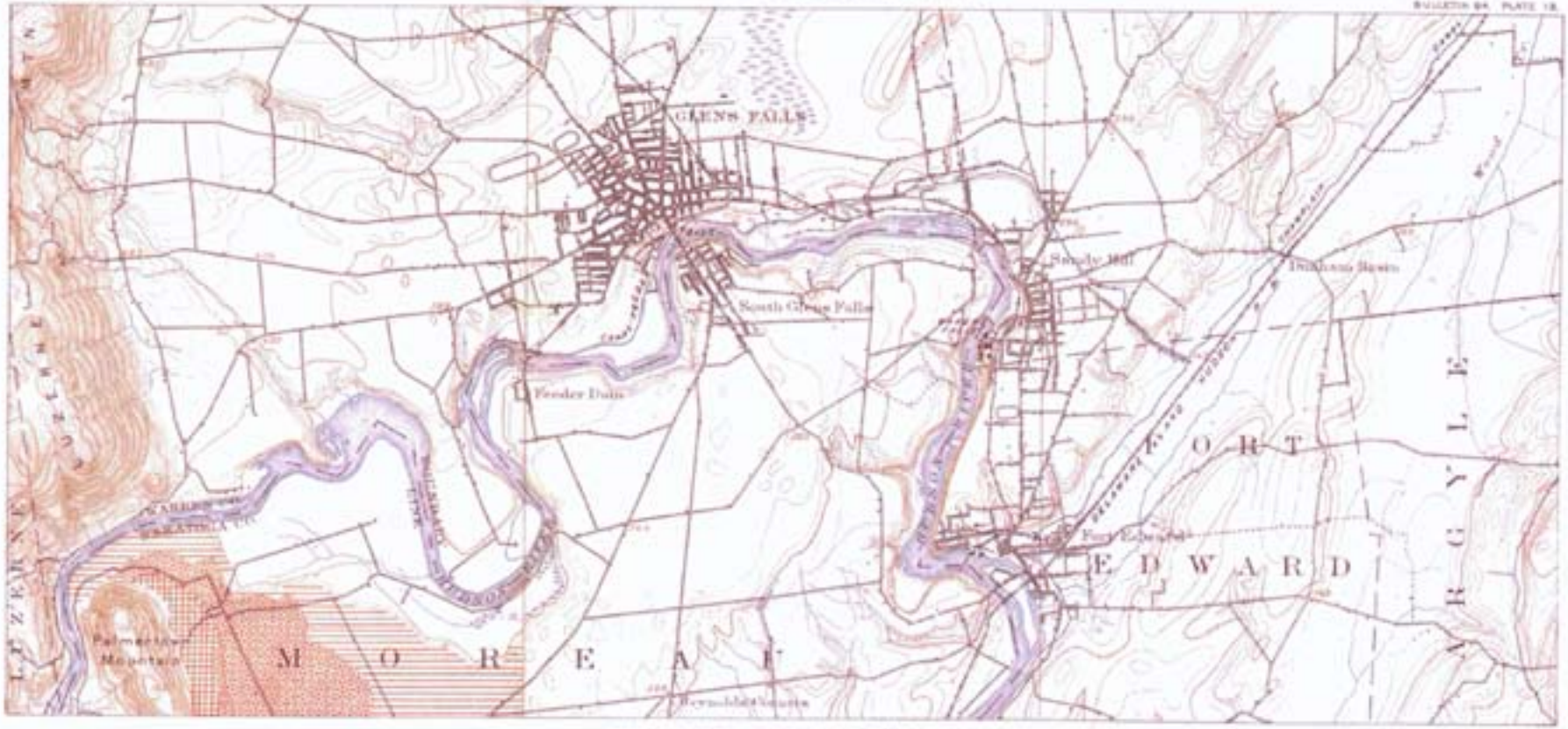
Palmertown mountain terrace [*see* Glens Falls quadrangle, pl. 13; *also* fig. 18, p. 139]. At the eastern base of Palmertown mountain there is a well developed terrace rising from 50 to 60 feet above the level of 400 feet. This terrace varies from ⅓ to ½ mile in width and near the Hudson river is cast into mounds and kettles proving its deposition in the presence of the departing ice sheet. In its northern part it is a typical kame terrace, and its eastern face or slope marks its original constructional limit against the border of the ice lying south of the present course of the river.

The materials of the terrace are exceedingly coarse cobblestones. With an ice barrier stretching across the mouth of the Hudson canyon, the water would be held back and caused to flow out at the lowest point of discharge which appears at this time to have been at Corinth. With the beginning of the retreat of the ice from the mountain wall the water would find an opportunity to pass along the eastern base of Palmertown mountain southward over the district about Gansevoort. It was apparently during this condition of drainage that the Palmertown mountain terrace arose, the terrace being the then bed of the river, and consequently above sea level.

Below and east of this terrace stretches another, a broad delta terrace, meeting the base of the earlier deposit at an elevation of 400 feet and probably marking a further marginal retreat of the ice sheet and a consequent lowering of the level of the glacial Adirondack-Hudson river [*see* fig. 20, p. 146].

Glen Lake kettle terrace. Small isolated terraces occur on the flanks of Luzerne mountain at the 500 foot and even higher levels marking the recession of the ice from the eastern flanks of the Adirondacks south of Lake George. It is not necessary to suppose that these deposits were ever much more continuous than they are now but below them at the base of the mountain extends one of the broadest and heaviest though not the longest glacial terraces seen anywhere in the Hudson valley. This deposit incloses Glen Lake, the central and largest example of

SOUTHERN THIRD OF THE GLENS FALLS QUADRANGLE



The geologically colored areas show successive stages of the retreat of the ice-sheet from Palmertown mountain and of the adjustment of the Adirondack Hudson river to the country freed by the ice.

THE REGION ABOUT FORT EDWARD.

Scale miles

Contour interval 20 feet

Datum is mean sea level

Kame-Kettle terrace.

400-foot Delta Plain.

250-foot Plain.

The remarkable trough from Fort Edward to the northeastern corner of the map extends the Hudson gorge into the Champlain valley. Another trough, not so deep, is shown two miles east of Fort Edward. These troughs served as outlets to Lake Vermont.

a group of deep ice block holes and kame kettles, the most extensive in the entire length of the Hudson and Champlain valleys. This terrace begins on the south near the Hudson river in a narrow shelving deposit having an elevation according to the contoured map of about 420 feet. Two miles north of the Hudson river, the terrace or at least a higher level of the deposit attains an elevation of 482 feet. From this point the front of the terrace trends northeastward toward Round pond. Following along the base of Luzerne mountain, the level of the terrace rises to about 500 feet at the distance of 4 miles from the Hudson river; and at French mountain station the surface attains a hight of 548 feet.

The front of the terrace passing northeastward at a distance of 2 miles northwest of Glens Falls rises from 50 to 100 feet above the more thinly drift-covered surface at its base. The summit line of the terrace front rises to about 480 feet except where gnawed back by streams. This frontal slope is an ill characterized bluff neither lobate like the front of a delta built in open water nor with stratified gravels and sands standing at the angle of repose as in old stream-cut terraces now healed by gravitative slipping. The detritus at the front is perceptibly coarser than over the top remote from the brow of the slope and boulders are not uncommon along its extent, an assemblage of features, weaker than usual, but indicating undoubtedly the deposition of the materials of the terrace in an open space lying between the base of Luzerne mountain and the ice mass which still lay over the central part of the Fort Edward district. The large kettle and ice block holes representing outlying partially or wholly buried blocks of ice give strong support to this view.

Patten's Mills terrace. Between Patten's Mills and Sugar Loaf mountain in the southwest corner of Fort Ann township [*see* Glens Falls quadrangle, pl. 14], the border of the large mass of ice covering the Fort Edward district is again marked by marginal deposits but in this case on the north. These deposits assume the form of a high gravelly terrace attaining an elevation of about 520 feet near the southern margin, and sloping gently northward, partially inclosing in that direction a lake-

let between the 480 and 500 foot contour lines. This lakelet probably owes its existence to a remnant of ice on the north, separated from the Fort Edward mass during the stagnation of the ice south of the mountain passes. The nature of the bottom of the lakelet has not been determined but presumably there is bed rock close underneath. Both clays and bed rock appear eastward near West Fort Ann village in an extension of this ridge.

West of this outwash deposit and north of Queensbury village, there is developed between the 420 and 440 foot contours a deposit having in its highest part, where it confronts the northwestern margin of the Patten's Mills terrace, a large depression or kettle hole, shown by the contours on the Glens Falls sheet [*see* pl. 14]. This depression also shows that ice remained on the northern side of the Patten's Mills deposit independently of the evidence afforded by the small lakelet, and renders it probable that the slope of the ground in that vicinity from the 480 down to the 440 foot line is also an ice contact feature.

Morainal terrace at North Argyle. About 1 mile east of the village of North Argyle on the Fort Ann quadrangle is a rock ridge culminating in a point 1037 feet above the sea. The ridge extends northeast and southwest. At its western base overlooking the Fort Edward district from the east is a terrace of glacial till rising over 120 feet above the low ground at its base and having a maximum elevation at the summit of about 600 feet. This terrace appears to have been deposited by live ice and presumably is of somewhat earlier date than the stratified deposits found elsewhere on the north and west at somewhat lower levels.

North of Evansville in a similar position in relation to an older rock ridge and in nearly the same alinement a till terrace rises from the west bank of the Moses kill with its mass between the 500 and 600 foot contour lines.

None of these deposits afford other clues to the level of the waters which may have stood in this district subsequent to the disappearance of the sheet than by their negative character—the absence of later clays and wave marks over their surface. It



THE GLEN LAKE AND OTHER SIMILAR ICE-BLOCK HOLES

And the Pattens Mills Terrace

Scale 1/62500

1 mile

Contour interval 20 feet

Ice-block holes

The Pattens Mills terrace

The "ice-block holes" mark the sites of remnants of the ice-sheet around which gravels and sands were washed.

The Pattens Mills terrace was formed on the northern margin of a part of the glacier covering the southeastern part of the area.

A part of the Fort Edward outlet of Lake Vermont is shown in the southeast corner.

is to be concluded from them that in this latitude neither large glacial lakes nor the sea rose so high as the surface of the lowest of these deposits. Much more detailed study of the region than I was able to give it in the search for water levels will be required in order to trace out fully the limits and history of the retreating ice mass of the Fort Edward region.

Fort Edward district below the glacial terraces. Below the marginal terraces above described as lying about the Fort Edward district, there are several well marked types of glacial deposits and a varied topography indicative of successive stages of development through deposition and erosion by water action. Not all of these deposits are pertinent to the inquiry concerning water levels.

From the vicinity of Glens Falls northwestward to the base of the Glen Lake terrace and thence northward and eastward

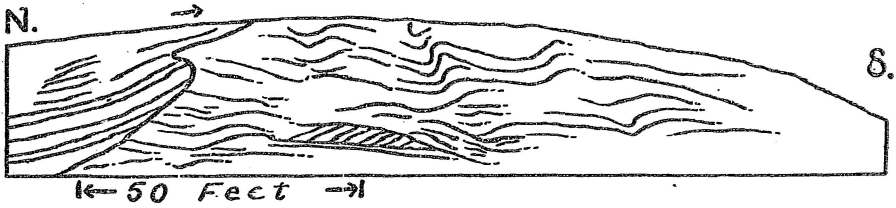


Fig. 19 Dislocated and overthrust clays, just north of Summit station, looking east, showing overthrust to the south

over the gently rolling country between Patten's Mills on the north and Argyle on the east, knobs and hillocks rising above the level of the clays are till covered or strewn over with glacial erratics. Such are the features observed in traveling from Sandy Hill northeastward to Vaughns or Queensbury. These hillocks, mostly outliers of the Lower Silurian limestone, rise from a rather uniform level of 280 to 380 feet to elevations of from 25 to 50 feet above the surrounding surface. Their drift-covered surfaces indicate that the ice mass, which defined the limits and the breadth of the terraces on the north and west of the basin, on melting left its unassorted debris on the region. The clays in the lower places of this surface indicate the subsequent covering of the district by standing water.

As elsewhere observed, the clays in the floor of the trench of Wood creek northeastward of Fort Edward are ice worn.

Further indications of the overriding action of ice are found south of Fort Edward quite within the gorge of the Hudson at Summit station on the electric railway line. The annexed figure is intended to show the nature of the disturbed clays as seen shortly after the excavations for the line were made [fig. 19].

Similar disturbances in the drift deposit were described by Fitch as being visible when the Delaware & Hudson Railroad cuts were made south of Fort Edward. All the evidence points to the conclusion that after the deposition of clays over the Fort Edward district at a time when the ice front had retreated an unknown distance to the north, there was an advance of the ice probably as far south as the mouth of the Moses kill within the Hudson gorge.

Deposits in Argyle and Hartford. On the east of the Fort Edward district, the morainal terraces at North Argyle and Evansville have already been described. Below these in the valley of the Moses kill in the region of the swamp north of Evansville are bordering kames and gravel deposits also laid down in the presence of ice.

Clays begin to appear in the upper reaches of small valleys at about 320 feet, as in the branches of Big creek southwest of South Hartford. Below this level the clays cover wide tracts, particularly from 300 feet downward to the margin of the Wood creek channel. These clays are everywhere incised by the numerous small streams of the region.

Glens Falls delta of the Hudson. The ice dam across the mouth of the gorge of the Hudson at the base of Palmertown mountain has already been described in its effect on the course of that river and in its bearing on the glacial terraces of that region. When the ice finally melted away from the low grounds about Fort Edward normal river and lacustrine deposits began to make. The gravelly and sandy delta of the Hudson spreading from the base of the glacial terraces at the mouth of the Adirondack canyon outward to Sandy Hill and Fort Edward was untrammeled in its development by confining masses of ice unless it be on the north side of the Hudson in the region about the city of Glens Falls. This delta is approximately 350 feet in elevation, rising to 360 feet according to the map at the base of the 400 foot or

second lower terrace at the base of Palmertown mountain [*see* pl. 13]. The low escarpment which separates this lower delta plain from the broad 400 foot terrace is a striking cliff of gravels sweeping southward from the Glens Falls quadrangle to the Schuylerville quadrangle on the south. As will be shown later its base corresponds closely with the presumed level of a stage of the glacial lake which covered this district and wave action is to be suspected as determining the form of the terrace though an earlier ice contact slope may have given rise to its position. The topography bears every mark of having been produced by erosion.

The delta of this stage evidently extended as far east as Sandy Hill and perhaps much farther toward Fort Edward. The southern and eastern margin of the present delta plain have been determined by erosion accomplished during the lower and later stages of the waters in which the delta was deposited.

The Hudson in its eastward course from the portal of the Adirondack canyon lies mainly on the north side of the delta as does the Mohawk in relation to the delta extending from Schenectady to Albany. There is a narrow strip of delta sand west of Glens Falls but within a mile north of the town and the bank of the river there is little or no evidence of stream-borne waste. Had the stream at any time wandered into this marginal field of its delta before sinking its present channel the river would easily have fallen into the course of Half Way creek and so joined the Champlain drainage. It is to be suspected that, where streams flow along the northern margin of old deltas built into glacial lakes of meridianal valleys, their courses were determined by the natural tendency to diversion into the depression which would arise on that side of a delta through the retreat of an ice barrier. No satisfactory evidence of the presence of the ice on the north side of the Glens Falls delta at this stage has been observed. In fact the continued development of the deposit since it might outlast the presence of the ice, did such a condition exist at the commencement of the process, would tend to obliterate those evidences of the ice contact on which the proof of the existence of preglacial deltas must ever depend. Other postglacial changes

are seen on the surface of the delta in the sand dunes which have there developed.

Along the southeastern border of the delta the land drops off to a clayey terrace lying between 250 and 280 feet in elevation. It is well exhibited at Reynolds Corners [*see* pl. 13]. The slope from the 350 foot delta plain to this lower terrace from Fort Edward southward coincides closely with the boundary between the Calciferous-Trenton limestones and the Hudson river shales which lie on the east of them. But the immediate origin of the slope appears to be due to erosion taking place subsequent to the formation of the 350 foot delta. This lower terrace corresponds in position with a tilted water plane of a glacial lake whose outlet on the south, as is shown on plate 28, was in the

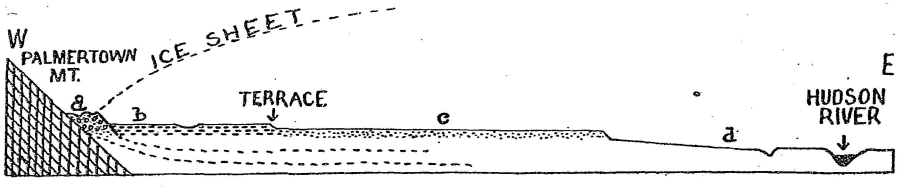


Fig. 20 Profile of the terraces and delta levels from the base of Palmertown mountain to the Hudson river. *a*, The glacial terrace; *b*, the broader terrace at 400 feet; *c*, the delta of the Hudson; *d*, the clay terrace, a part of the channel of the stream which flowed through the Coveville outlet

old channel back of Schuylerville which falls into the Hudson gorge at Coveville.

Below the level of this terrace is the old channel continuing the Hudson gorge by way of the Wood creek valley to Lake Champlain, the evident path of a river which as I shall hope to show later in this report drained a glacial lake in the Champlain valley into the Hudson gorge. East of this channel is a branch at a somewhat higher level perhaps earlier occupied by the same stream before that nearer Fort Edward was so deeply excavated.

The above diagram, figure 20, is intended to show by an east and west profile the successive terrace and delta levels of the Fort Edward district, down to the existing channel of the Hudson below the site of the old fort.

The effect of ice barriers and glacial lakes about the southeastern base of the Adirondacks is so well exhibited in the case of the Hudson river that the following digression is introduced

partly to summarize the evidence and correlate the delta deposits of this region.

The three deltas of the Adirondack Hudson. The Adirondack Hudson river has three deltas of late glacial age at the southeastern base of the mountains, one at Corinth, one at Gansevoort, and a third at the base of Palmertown mountain. The river flowing southward through the Precambrian rocks of the Adirondacks touches at Corinth on the northern end of a fingerlike projection of the Cambrian and lower Silurian strata let down by faulting within the walls of older rock, but instead of following this tract of newer rock southward to the open ground toward Ballston, the river now turns rather abruptly eastward across a broad tongue of the Precambrian rocks and emerges on the Fort Edward district through a deep gorge in the Adirondack *massif* just above Glens Falls.

When the ice sheet in its retreat had its front in this region, the pressure through the Champlain trough appears to have maintained a barrier of ice against the eastern wall of Palmertown mountain, thus preventing the escape of the river in that direction while the path southward from Corinth was open. Hence the river discharged its waters, laden with gravel and sand, through the broad valley followed by the Adirondack Railroad from Corinth southward. In the earlier stages of the melting of the ice from this valley a very high and massive kame terrace was built on the western margin of the ground held by the delta at the next stage of building.

These kames with their kettles here and there holding lakelets are very conspicuous for a mile or more south of the railroad station at Corinth. At the time the deposits were formed, ice must have occupied the valley below and have extended eastward perhaps in continuity with the sheet lying over the Fort Edward district.

The village of Corinth stands on the northern edge of the delta which has the form of a rather steeply inclined outwash fan flooring over the valley with its crest on the north overlooking the river. The present examination of the region was not carried beyond this point to determine to what extent the Hudson valley above Corinth was free from ice at the time the delta was formed.

As soon as the ice shrunk away from the eastern base of the mountains at and south of Palmertown mountain, a lower course was open to the river which now escaped along the eastern base of Palmertown mountain and flowed between the ice and the mountain wall till the ice front was reached, there spreading out the broad plains of gravel and sand near Gansevoort on the margin of the body of water in which the Albany clays were depositing. At this time the ice evidently stretched eastward across the upper Hudson valley at the southern margin of the Fort Edward district. The Gansevoort delta at present largely modified by the drifting

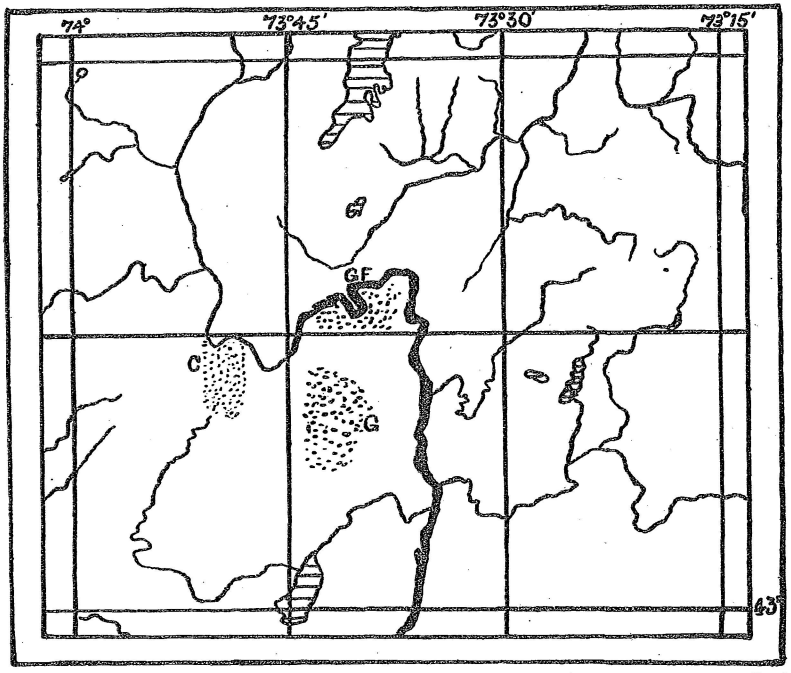


Fig. 21 Sketch map of the three deltas of the Adirondack-Hudson. C, the Corinth delta; G, delta near Gansevoort; GF, the Glens Falls delta

of its fine sands by the winds has its inner upper level at 325± feet above sea level. It forms a broad gently inclined fan without very definite outer margin, indicating that the water level of Lake Albany was somewhere between the 300 foot and 325 foot lines above the present sea level.

Along its northern margin the delta is broken by large kettle holes containing small lakelets showing the approximate position

of the water-eaten margin of the mass of ice which lay over the Fort Edward district at the latest stage in the delta construction.

It was probably at this stage that the terrace of coarse gravels lying at the base of Palmertown mountain was deposited. An intermediate stage is marked by the small terrace on the flank of the Hartman terrace lying on the north bank of the river just within the Adirondack gorge of the Hudson.

Afterward followed the several stages of broad terrace building described as margining the Fort Edward district on the west, ending in the delta which spreads forward from the mouth of the Adirondack gorge toward Glens Falls on the south side of the river. The ice front or at least the southern margin of the remnant which lay over the district may have lain along the northern bank of the Hudson from the gorge toward and beyond Glens Falls, preventing the delta from building on the north side of the present channel. As the ice shrank away from the delta along its front, the stream fell into the depression thus made and so found its way across the limestones and shales past Sandy Hill to the old gorge at Fort Edward, thus establishing the connection of the Adirondack-Hudson with the main channel.

Delta of the Mettawee river. The Mettawee river crosses the northeastern part of the Fort Ann quadrangle in Granville and Whitehall townships. In the western part of Granville the roughened plateau of eastern New York falls off to the lower levels of the town of Fort Ann within the clay-covered ground east of Wood creek. Clays cover the surface up to approximately the 300-foot contour line. Opposite the valley of the Mettawee, within the eastern plateau in the vicinity of West Granville, a gravelly and sandy delta of the Mettawee has a small development much less extensive than the deltas of the Batten kill and the Hoosic river farther south.

The head of this delta is about 320 feet in its present elevation above the sea, passing into terraces at North Granville which rise gradually up the valley and attain a level of 400 feet at Middle Granville. The delta slopes gently outward to the 300 foot contour north and south of West Granville and there gives way to the clays which mantle the lower grounds northward to Whitehall and southward into Hartford. It is safe to assume

that the water level marked by the delta lies between the 300 and the 320 foot contour lines.

The slight development of the Mettawee delta on the margin of the Hudson-Champlain valley as compared with the extended deltas of the streams of similar size today on the south appears explicable in the view that the deposit did not begin to form till the ice which covered the Fort Edward district melted out. It has been shown in the account of the Fort Edward district that there are strong reasons for believing the ice front lay for some time on the south of that district between Fort Edward and Schuylerville. Into the water body covering the clay grounds south of the ice front, the Hoosic, the Batten kill, and other streams farther south were building their deltas and continued so to do while the water was maintained at the level of the delta margins.

The Mettawee turning northward along the eastern margin of the delta has cut a deep trench into the underlying clays and now flows over the bed rock with low falls about 1½ miles below North Granville.

The delta of the Mettawee correlates with the inclined water plane of a glacial lake at the Coveville stage, as shown on plate 28.

Delta of the Poultney river at Fairhaven Vt. The Poultney and Castleton rivers join near Fairhaven Vt on a broad gravelly plain overlying glacial clays. This plain has an elevation of about 380 feet. It is inclosed, except for a pass on the west followed by the Rutland branch of the Delaware & Hudson Railroad and on the north by the valley through which the Poultney escapes, by high land, and thus appears not to have been a delta built on the margin of an open sheet of water as was the case with the deltas of the Mettawee and other streams on the south.

The delta of the Poultney lies between the more marked levels of the tilted water planes which converge on the outlets of a glacial lake below Fort Edward. It would appear therefore to have been made in a narrow valley opening westward on a glacial lake. Much more detailed work will be required in order to correlate satisfactorily these deposits on the Vermont side of Lake Champlain. The surface of the deposits at Fairhaven

lie only a few feet above the tilted level of the lake in which the Granville delta was made, and appear to be correlated fairly with the Coveville stage.

At Carver Falls, a terrace exists at practically the same level, but the reconnaissance of the district has not sufficed to determine any definite relation which this deposit bore to the retreating ice or to the lake which stages once existed over the lower ground in the region about Whitehall. It is to be observed that at Dresden Center on the west side of Lake Champlain and nearly due west from Carver Falls clays occur from the lake shore up to about the 380 foot line.

Partial summary. Within a radius of about 5 miles on the east, north and west of Glens Falls, there are deposits made in the presence of lingering ice. These deposits form terraces of varying width, with their summit planes at altitudes varying from about 440 to over 500 feet in elevation. These terraces appear to have risen above the level of the clay-depositing waters which later covered the lower roughened plain of the Fort Edward district.

The low rounded clayey hills along the line of Wood creek between Fort Edward and Fort Ann are composed of glacial clays evidently overrun by an advance of the ice and strewn with small boulders. Following this there is evidence of the extension of the Hudson delta at the 350 foot level spreading sands as far east as Sandy Hill at lower levels beneath the water surface. Clays made over the higher ground on the east in Argyle nearly to the level of the delta. Still later there are evidences of powerful currents passing southward through the district into the gorge of the Hudson. In a later chapter it is thought the explanation of these phenomena is found in the series of outlets for a glacial lake which extended from the southern border of the Fort Edward district northward through the mountain passes into and over the Champlain valley to the ice front stretching between the Green mountains and the Adirondacks.

Chapter 5

RETREAT OF THE ICE SHEET IN THE CHAMPLAIN VALLEY

The retreat of the ice sheet in the Champlain valley has been largely obscured by the extensive modification of deposits at low levels through the action of waves and running water. In only one portion of the field was much attention paid in the course of the present investigation to the ice retreat and at no point in the length of the lake am I at present able to state the precise line of ice frontage across the lake valley. The following notes on such localities as chanced to be examined in the course of the search for water levels by no means give a complete account of the recession.

As will be noted from allusions in these descriptions and from the conclusions to which I have been led, a glacial lake appears to have extended northward in the valley pari passu with the retreat of the ice front. Still earlier as remarked by several observers there were probably lakes held in along the margin of the ice sheet both on the Adirondack and Green mountain sides. Taylor has given the name of Lake Adirondack to such a body of water whose traces he recognized in the region back of Plattsburg. Probably other similar lakes existed in the upper basins of the Winooski and Lamoille rivers in Vermont [*see* pl. 27]. Some or all of these marginal lakes must have later become confluent with or drained into the greater lake which was held in by the ice sheet while its front stretched across the valley from the Green mountains to the Adirondacks.

Mr Baldwin has supposed this front to have been concave northward on account of the melting effect of the water which bathed it. This need not necessarily have been the case, however, provided the rate of the forward movement during the retreat counterbalanced or exceeded at times the rate of melting. My studies on the Mooers quadrangle have led me to an opinion just the opposite of that expressed by Mr Baldwin. All the phenomena in that area show that the ice was "alive" even at this late time in the retreat. It built frontal moraines; it maintained its frontage for some time along the margin of

remarkable spillways despite the favorable conditions for backward melting owing to the presence of water warmed by flowing over bared rock; it had in that area a northwest-southeast alinement and in consequence of its power to press high up on the Adirondack slopes must have been able to maintain a more or less lobular frontage across the Champlain valley.

Mr Gilbert, it should be stated, has described to me deposits on the northern side of Covey hill in Canada which he interpreted as indicating the return of the ice sheet after it had disappeared from that vicinity. The evidence consists of what appears to be a patch of frontal moraine between two marine beaches.

In a very suggestive paper on this region Mr Upham has expressed the belief that in the very latest stage of the ice retreat from the St Lawrence valley, the ice stood in such a position still as to debar the sea from entering the Champlain valley but to permit the confluence of the glacial dammed waters in that valley with those over the upper St Lawrence and Ontario valleys. I am not able at present to affirm or deny the pertinency of this view.

The following details concerning glacial deposits serve to show the general character of the latest stage of ice action in the State.

Dresden gravels. A conspicuous deposit of glacial gravels occurs in the southern constricted portion of Lake Champlain at Dresden station on the Delaware & Hudson Railroad, and extends southward toward Chubb's Dock. The deposit is also exposed at Cold Spring on the Vermont side, where the gravels are screened and shipped in canal boats for use as road-metal.

The gravels show alternations from very fine to relatively coarse sediments with a stratification characteristic of outwash deposits. The materials in the terrace at Dresden become perceptibly finer southward, indicating that at the time of their deposition the drainage from the ice was southward through the Wood creek channel into the Hudson valley.

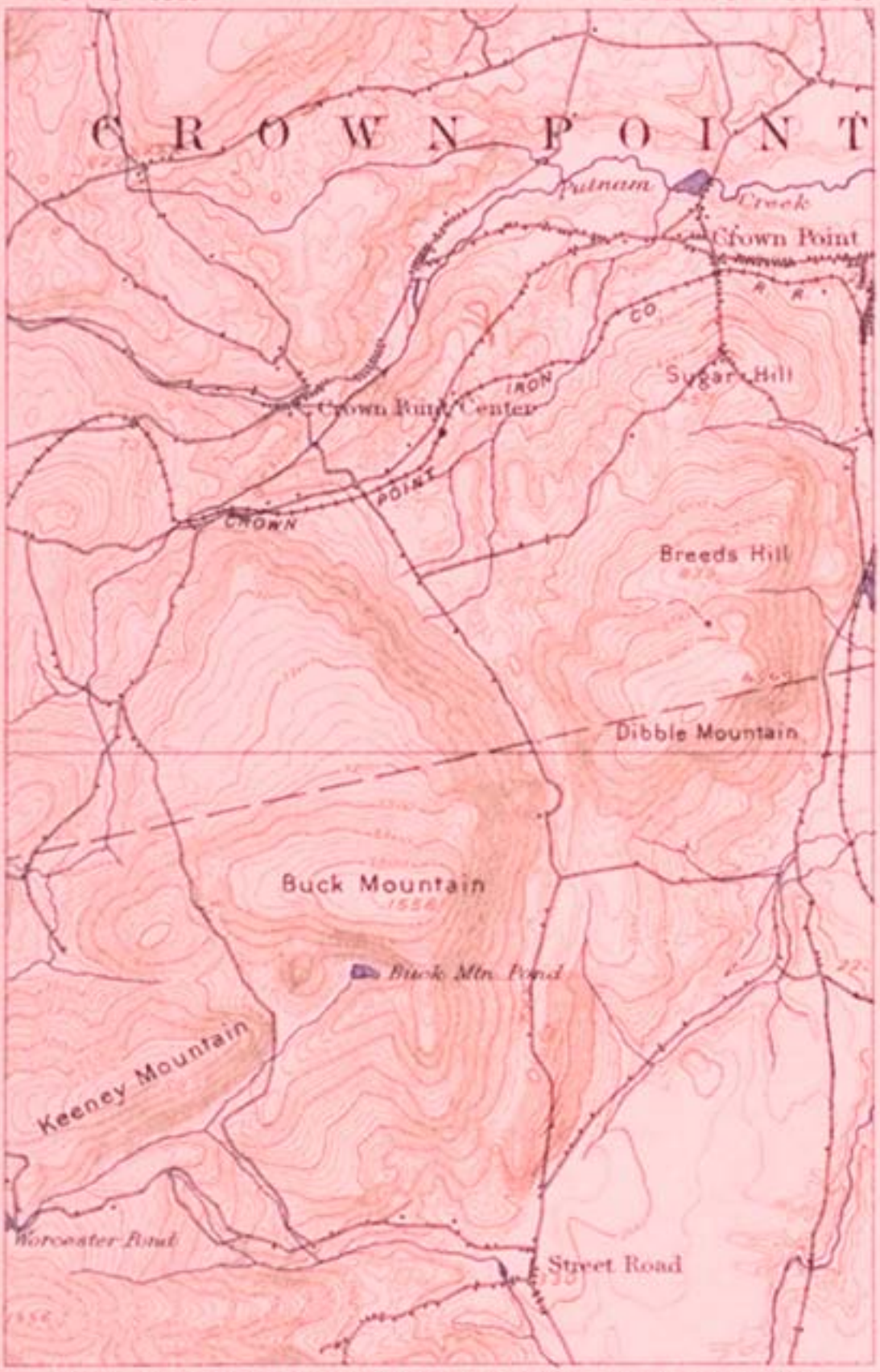
The coarse gravels which occur throughout the section indicate that if standing water existed at the time of their deposition, its surface was much below the level of that in which the subse-

quently formed clays were laid down in this district. Any great depth of water would have made it difficult for a current either in the ice or outside of it to transport such coarse materials at the bottom. From Dresden southward to Chubb's Dock, the so called Champlain clays rest on the uneven and often kamelike surface of these older gravels and sands.

Such amassments of gravel have already been noted in the Hudson valley occupying a like subjacent position to the Albany clays, as at North Albany and in numerous sections from north of Cohoes to the point where the stream draining Round lake falls into the Hudson. The deposits are evidently glacier margin deposits associated with the final melting out of the ice. If the structures of these gravel deposits at North Albany and Dresden have been correctly interpreted, it would seem as if for a time at least the land must have been higher than it was during the lake stages in which clays were deposited and high enough in relation to the southern Hudson valley to permit a rather free run off of the glacio-natant waters. The isolated facts cited from the talus at the southern base of Skene mountain at Whitehall and the similar phenomena east of Saratoga lake [*see* p. 136] strengthen this conclusion—that changes of level were taking place during the retreat of the ice sheet. This particular movement appears locally to have affected lands lying above sea level. Its recognition carries with it, in view also of the marine deposits which followed, the assumption that following the disappearance of the ice from this portion of the valley a reversed movement set in by which the land was lowered on the north relatively to the southern part of the State so as to produce an uplifted barrier in that direction capable of retaining the waters which formed the lakes whose records are so clearly shown in the succeeding deposits of clays and marginal sand deltas. It must be borne in mind, however, that these earlier movements preceding the clearer records of the glacial lakes and the marine invasion depend on scattered and fragmentary evidence which further study of the district may prove in a better light to be capable of a different interpretation.

Street Road terrace [Ticonderoga quadrangle, pl. 15]. North of Street Road and at the eastern base of Buck mountain there

PART OF THE TICONDEROGA QUADRANGLE



THE STREET ROAD LATERAL MORAINE TERRACE

And some of the clearer shore-lines about Crown Point

Scale 1/62500

1 0 1 2 Miles

Contour interval 20 feet.

Datum is mean sea level.

Lateral terrace

Morainic deposit.

Eskerlet.

Kettle-hole.

Wave-lines.

filled by the wash which would have been drifted into it by wave action at its own level.

Possible local glacier at Port Henry. The presence or absence of local glaciers in the Adirondacks and neighboring mountains of New England continues to be a mooted question. Several writers have reported what has appeared to be evidence of local glaciation following the disappearance of the Laurentide glacier from the Adirondack mountains. Till detailed mapping of the area shall have been undertaken the question is likely to remain more or less open. The importance of the question can not be gainsaid in an investigation of the water levels which have existed in the Champlain valley in view of the possibility of ice dams which may thus have been introduced and maintained after the withdrawal of the Laurentide ice. A few observations of the writer during the present investigation of the foot region of the Adirondacks have prepared him to find that local glaciers may have extended near enough to sea level in the time of depression to have interfered with the development of normal shore phenomena, but much more careful work is required before it can be asserted that the phenomena already seen prove the existence of local glaciers.

The question of local glaciers has been raised in the present survey mainly by the abnormal striation and the lateral moraine terrace at Port Henry and by the faint traces of a late north-south striation about the northern border of the Adirondacks where the earlier Laurentide ice in diverging lines of flowage moved up the St Lawrence valley on the north of the Adirondacks and up the Champlain valley on the east of this obstruction to its flow.

Port Henry lies on the western shore of Lake Champlain at the foot of a broad depression in the high hills which confront the lake for several miles on the north and south. The floor of this depression rises westward and expands north and south for a few miles. Still farther westward the ground rises more rapidly into the highest part of the Adirondacks. Along the shores of the lake north and south of this depression roches moutonnées with rounded northern backs and cliff like southern fronts together with northsouth striation attest the southward

PART OF THE PORT HENRY QUADRANGLE



GLACIAL DEPOSITS AND SHORE-LINES ABOUT PORT HENRY

Scale 62500

1 0 1 2 Miles

Contour interval 20 feet.

Datum is mean sea level.

Lateral moraine terrace. | Glacial striae. | Frontal (?) moraine. | Shore-line. | Gravel terrace. | Sandy deposit.

flow of the Laurentide stream of ice through the Champlain valley. In the village of Port Henry, near the Lake Champlain and Mineville Railroad station, well developed nearly eastwest glacial striae indicate a movement later than the main glaciation and normal to it. The striation referred to is n. 68° e. Again ½ mile south of McKenzie brook along the street between the 300 and 500 foot contour lines, glacial striae occur having a more nearly east and west (n. 83° e.) direction. In the southwestern corner of the Port Henry quadrangle, just south of the red schoolhouse, glacial striae with a course n. 43° e. cover a well worn ledge. Beginning on the north again in the bed of Mill brook at a point north of the road crossing the stream about ¼ mile southwest of the race track, there are glacial striae running n. 80° w. South of the road crossing, striae of the northsouth set occur. These localities are shown on the accompanying map [pl. 16].

Northwest of Port Henry at a distance of 1 mile begins a spur of foothills at the western base of which runs Bartlett brook, the north branch of Mill brook. The western slope of this spur carries a well defined lateral moraine terrace which projects beyond the rock hill on the level ground west of the race track. From this point, the surface of the terrace rises rapidly to the northward for about a mile beyond which no attempt has been made as yet to trace the deposit. The terrace can be plainly seen from the Mineville Railroad near the upper switch back. The presence of this terrace in this position seems to indicate clearly that the margin of an ice mass rested against this western slope of the spur. One mile south of the southern end of this deposit, south of the valley of Mill brook and the north branch of McKenzie brook, the land rises to the 800 foot contour line and is crested with a recognizable hummocky moraine.

Three hypotheses suggest themselves at once in the explanation of the peculiar striation of this area. First, the abnormal striae were produced by the westward protrusion of the margin of the Champlain lobe at a time when it was mainly confined to the walls of the lake valley and pressed against though it did not overtop the foothills. Wherever a low place in the valley wall

presented itself, it might be expected that the ice would deploy into it. Second, these local striae are due to a branch of the main Champlain lobe which passed southward through the mountain valleys on the west and rejoined the main lobe at Port Henry. Third, the striae are due to a local glacier or to small glaciers coming at least to within 60 feet of the present lake level from snow fields in the high area on the west, whose culminating point, Mt Marcy, is 24 miles distant in a west by north direction.

The position and nature of the till deposits of morainal character shown on the map are explicable by the second and third hypotheses. The fact that the eastwest striae extend quite down to present lake level favors the first hypothesis on account of the difficult assumption that a local glacier would push its front to so low a level after the main ice had retreated from this latitude. On the other hand the striae near the present lake shore come to the shore so abruptly as to give no support to the first hypothesis. I was not able to make out from the details of the few striae observed whether the ice movement indicated by them was toward or away from the present lake. In the case of the ledge near the red schoolhouse southwest of Port Henry there are crescentic flakes in the gneissoid rock with the horns pointing to the northeast. I have seen similarly fractured pieces removed in which the horns of the crescent pointed in the direction in which the ice was moving. If that be true here it is a point in favor of local glaciation.

In the Mill brook locality, the glaciated ledge of the abnormal set was overlain by a gravelly boulder clay containing fragments of Potsdam sandstone, gneisses and limestones.

Bulwagga mountain comes to the lake front with a bold escarpment and, blocklike, rises between the depressed region of Port Henry and the similar area of Crown Point. In this latter side valley glacial striae, n. 42° e., were observed just south of the village on the north slope of Sugar hill. On the road from Crown Point Centre to Coot hill, glacial striae may be seen running n. 48° e.

Yet farther south of the west side of the lake in the vicinity of Ticonderoga, the striae range from n. 13° e. to n. 33° e., dis-

Plate 17



Frontal moraine ridges north of the Altona spillway between Altona and Sciota. Looking northeast

playing the draft of the ice in these localities into the Lake George passage. All the striae from Bulwagga mountain southward exhibit this southwesterly trend at a considerable angle with the axis of the main valley showing that the axis of the glacial line of flowage lay to the east of the present shore of Lake Champlain; but nowhere have I seen in this southern area within 800 feet above the lake such anomalous variations from the southward and southwestward striation as those which occur in the Port Henry area.

The other cases of glacial striation which fail to agree with that which is normal for the region are found in the meridional scores which occur in Clinton county, N. Y., in the town of Mooers and farther west between Cannon Corners and Clinton Mills.

A ledge of Potsdam sandstone at the sharp bend in the Great Chazy river between Thorn's village and Mooers Forks carries separated and rather faint striae running n. 19° w. The adjacent bank of the river is for the first 10 feet above the water composed of sandy till, largely Potsdam drift, which must originally have covered the rock here referred to. The neighboring normal striation is shown in a near-by ledge farther down stream to be n. 36° e.

A ledge on the Perry's Mills road 2 miles west of that village exhibits faint striae n. 16° w. Striae running n. 10° e. occur in the ditch on the south side of the Rutland Railroad, 1½ miles west by south from the bridge over the Great Chazy. Both of these cases depart from the maximum flowage direction which would be expected for the northeast corner of the Mooers quadrangle from what is known of the more abundant striation immediately southwest [*see* geologic map of the Mooers quadrangle, pl. 29].

A little less than 3 miles north from Ellenburg depot and at a point ½ mile south of the English river on the road to Cannon Corners, bare ledges of Potsdam in the road show abundant rather widely spaced striae whose direction is n. 10° w. The normal direction for this region according to observations on the northwestern corner of the Mooers quadrangle would lie between n. 46° e. and n. 61° e. The divergence between the normal

thickly set striae and the discrete evidently later glaciation is so great that it hardly appears probable that the two sets pertain to the movements of the same glacier even when account is taken of divergent flowage in a retreating ice lobe. In the case of the abnormal striation in the northeastern corner of the Mooers quadrangle, it is conceivable that the ice when it had become so thin as to be diverted by the Covey hill ridge, on the east of this elevated district turned more sharply than before into the Champlain valley; but the striae north of Ellenburg depot can not be so explained. The cases above cited recall the later separate striae described by Chalmers as occurring south of the St Lawrence near the international boundary opposite Vermont and New Hampshire and which have been interpreted by him as produced by local glaciers descending the mountains along the frontier of New England into Quebec. As yet no evidence of associated frontal moraines nor the northward transportation of erratics which would corroborate this view has been detected along the northern border of New York. Much further work in this region will be required to demonstrate the precise nature of these anomalous striae.

Southern slope of Rand hill and Dannemora mountain. A relatively late stage of frontal deposits is well developed along the southern slope of Rand hill and Dannemora mountain where the drift is very thick particularly opposite the notches opening northward through the mountain. The ice pressing against the northern side of these elevations appears to have pressed through the valleys and built up a shelving terrace of interstratified till and washed gravels on which the tongues of the glacier at times rested. From the evidence of heavy deltas between Dannemora and Lake Champlain there appears to have been standing water in this embayment at levels above that of the main body of water which later lay in front of the ice over the Champlain valley proper. Such is the delta at Cadyville on the Saranac.

Moraines north, east and west of Rand hill. Rand hill as shown in the report on the Mooers area [N. Y. State Mus. Bul. 83] is encircled with lines of retreatal moraine on the east, north and west [*see* pl. 17]. These moraines with the exception of a lower group to be more particularly mentioned show no signs of wave action or of attendant outwash plains constructed in



View in the Altona "flat rock" spillway, about ¾-mile northwest of "Dead Sea"; elevation 750 feet, looking s. 26° w.

standing water. Between the lowest of this group of frontal deposits on the north and the higher ones there intervenes the remarkable "flat rock" areas or spillways of Altona extending into the region northwestward as far as the international boundary at Covey hill, Canada.

Flat Rock spillways [*see* pl. 18]. These bared surfaces of the Potsdam sandstone mark the path of a torrential discharge of water held on the northern slope of the mountains along a line from the notch at "the Gulf" [*see* pl. 25] on the international boundary line to a point west of the village of West Chazy, a distance of about 19 miles. It is necessary to suppose that the ice front lay along the lower side of this spillway belt, which thus becomes quite as definite as a frontal moraine in the fixation of the position of the ice at this time. This line of evidence is confirmed by the occurrence of strong frontal deposits along the lower margin of the spillway zone near West Chazy at "Cobblestone hill" and northward [*see* geologic map of the Mooers quadrangle, pl. 29].

More important than all this is the evidence afforded by the torrential action concerning the hight of the standing water then in the valley of Lake Champlain. The lower margin of the stripped bed rock near West Chazy descends nearly to the 620 foot contour line; its upper limit in the district is approximately 900 feet; farther north its upper limit is as high as 910[1] feet, and in the Gulf there is a water pool [*see* pl. 19] at the base of an abandoned waterfall at 810[1] feet, and there is a lower lakelet in a chasm at 645[1] feet [*see* pl. 20]. These lakelets would not have been produced by a fall of water into this channel when it was deeply submerged. There are evidences of water standing at some episode in this phase east of the Gulf[2] at a level between

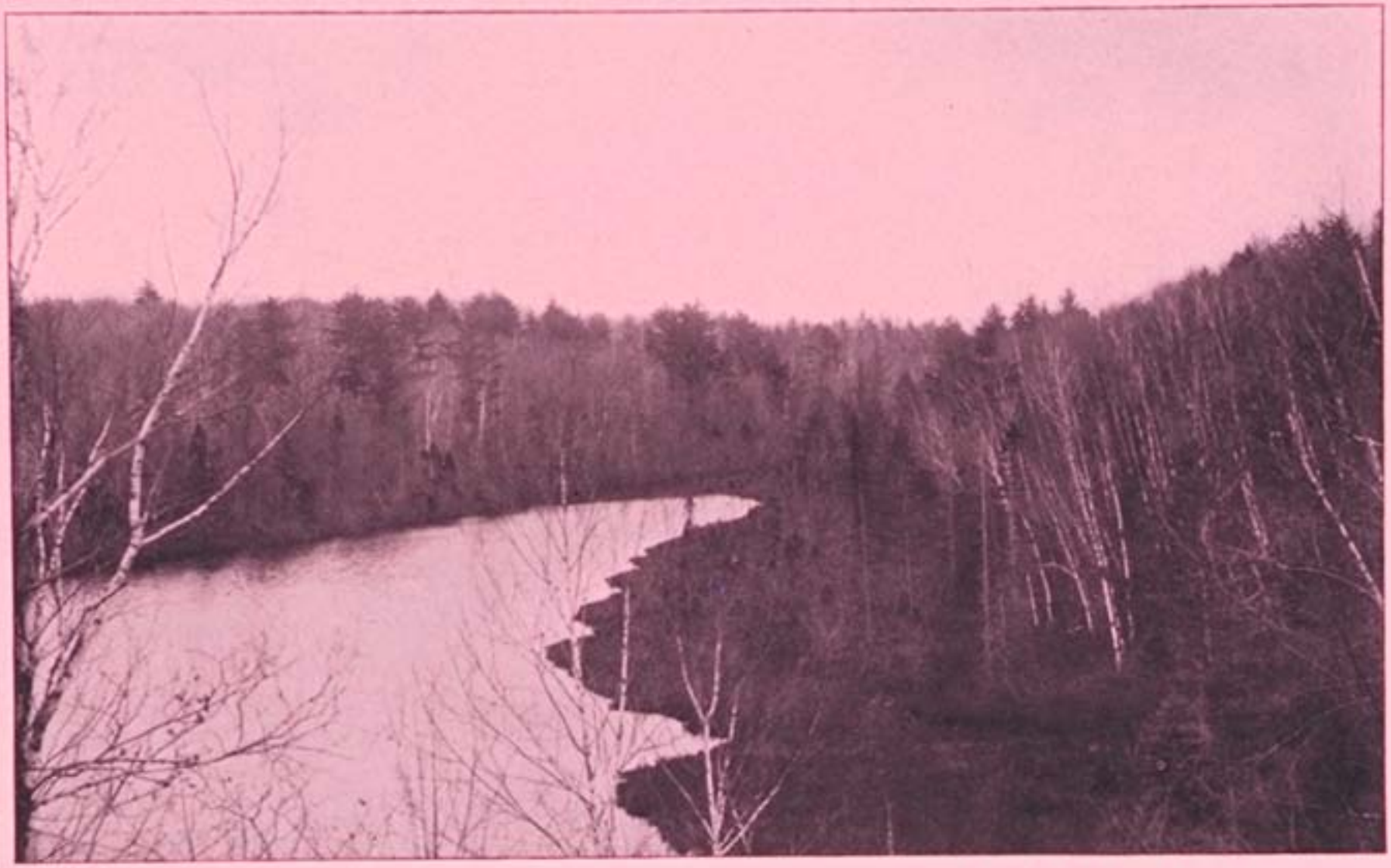
[1]These elevations are from Mr Gilbert's notes, but have been taken independently by myself.

[2]There is a brief account of the Gulf given by Ebenezer Emmons in the *Geology of the Second District.* [Clinton County, p.309–10, 1842] He reports the small lake at the bottom as "said to be 150 feet deep." He also states that "To account for the present condition of this rock, we have therefore to go back to a period when some current swept through this gorge with great force and power; for by no other means could the materials, which once filled the space between the present walls of the gulf, be removed." This is the first notice I believe of this spillway in scientific literature.

the levels of the two lakelets. An ice barrier extending to the north and west of Covey hill caused the waters along its front to escape through the pass on the south side of the hill. When that ice barrier withdrew from the northern slope of the hill it would have at once allowed the waters to take a lower channel around the northern slope of the hill and at the same time it would have removed the barrier which on the east of the hill retained the glacial lake at its high level. It can not be supposed therefore that any part of the Gulf was excavated after the ice sheet withdrew from the northern side of Covey hill. The occurrence of the high beaches on the northwest corner of the Mooers quadrangle at a level above the lower lake in the Gulf chasm, together with the line of beaches along the northern border of the Altona flat rocks—there lying above the lower limit of these rocks—makes it reasonable to suppose that after the scouring of the flat rock spillways had been well begun there was, at least at the northern end of the Champlain valley, a local relative rise of the water level as the ice receded and this would be a consequence of the downsinking of the land in this northern region. An uplift of the country about the lower Hudson would have accomplished the same result. That there was a local change of the first description is probable since as will be brought out more fully later, the shore lines in the Champlain district are more steeply inclined to the south than are the earlier water levels between New York and Albany. The reversed direction of tilting of the land to the south which has since taken place would produce the observed discordance if the land were tilted more and more to the north while the glacial lake advanced northward in the face of the retreating ice sheet.

Evidence from the northern face of Covey hill [*see* pl. 25]. As is shown in more detail in the report on the Mooers quadrangle, the northern face of Covey hill is a critical field for the study of water levels in the upper St Lawrence valley. Mr Gilbert appears to have been the first to perceive this point and was I believe the first to make critical though unpublished observations on this interesting locality. Covey hill and the Gulf are localities at which most lines of evidence presented in this paper come to a focus; hence the various features which are there presented will be found often under separate headings in this report.

Plate 19



View from north end of the gulf at Covey hill, looking east over the upper lakelet at 810 foot level. View in Canada

As regards the position of the ice front on the northern flank of the hill, it should be stated that as noted by Mr Gilbert the highest well defined and clearly demonstrable beach along this line is at 450 feet above sea level. But above this beach occurs a succession of rude terraces with coarse and often rather angular blocks from just above the 450 foot line to about 570 feet. Some of these are lines strikingly level for long distances; yet other parts of this system are inclined. All of them and particularly the highest show considerable cutting into the till cover of the hill. A till cliff is conspicuous at a number of localities on the north side of Covey hill near the 570 foot level according to my aneroid readings. Waterworn pebbles and characteristic beach wall structure are apparently absent. Mr Gilbert according to his notes in his search for beaches ruled all these higher lines out, if I understand his notes correctly, because of their lack of horizontality. Prof. A. P. Coleman who examined them in my company in 1903 hesitated at the time to pronounce them beaches. They lie for the most part in the zone of certain high and coarse beaches of angular and shingly debris which can be traced to the southeastward on the northern part of the Mooers quadrangle. The deposits deserve further study with careful leveling and mapping. If not due to powerful waves these terraces seem to me to demand powerful currents acting in the manner of the streams which Mr Gilbert and later Professor Fairchild have traced along the ice front in central New York between Syracuse and Rome. Such stream action between the ice front and the slope of the hill would cut effectively and make a part of the stream bed in the till with one bank of that material, and the other half of the bed might be formed by the ice with the bank on that side also of ice. It is to be expected that, as soon as the ice withdrew somewhat from the northern face of the upper part of Covey hill, the heavy discharge of waters which had taken place through the Gulf would have been diverted to the north side of the hill at a lower level. Farther south on the Champlain side there was a glacial lake with constantly lowering stages into which these torrential spillway levels would merge. Such is the interpretation which I have placed on these terraces above the marine limit of 450 feet on the northern flank of Covey hill.

Further consideration of the changes of the ice front and the water levels at this stage are deferred to the chapter on the glacial lake which then overlay the Champlain valley [*see* p. 168].

Summary of retreat of ice in Champlain valley. Less evidence of the position of the ice front from time to time is found than is the case in the Hudson valley. This paucity of evidence is partly due to the extensive deposits of clay and sand found up to elevations of 400 and in certain localities up to 700 feet along the slopes or in the embayments of the Adirondacks and the Green mountains. It is also partly due to the fact that there appears for a portion of the retreat at least to have been a lake lying over the district with conditions unfavorable to the formation of pronounced frontal deposits. Certainly no clear frontal moraines have as yet been traced across the Champlain valley floor.

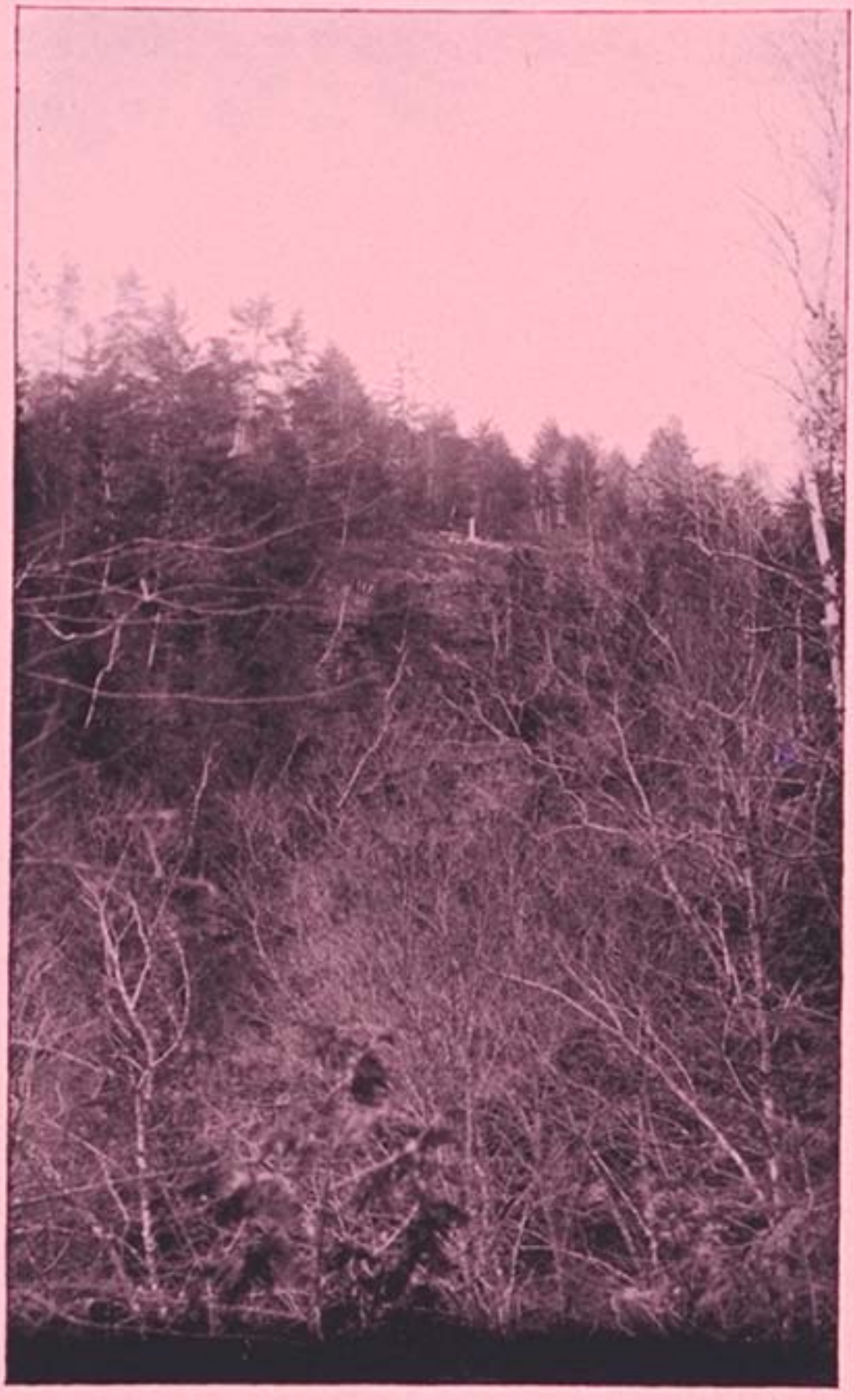
Small glacial lakes began to appear along the margins of the ice sheet as soon as it had shrunk to the dimensions of a mass merely filling the valley. In the numerous embayments on the western side of the valley, local bodies of water received delta-building streams from the back country.[1] The drainage of these waters was southward along the ice margin as shown by the southward building of the terrace at Street Road.

The question is raised whether or not a local glacier entered Lake Champlain at Port Henry, a point east of Mt Marcy. This and other localities of aberrant striation require further study in the field.

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[1]See paper by Frank Taylor on Lake Adirondack in bibliography appended to this report.

Plate 20



View along the boundary line between the United States and Canada where that line crosses the gulf; looking east

Chapter 6

VALLEYS OF LAKE GEORGE AND WOOD CREEK

The Champlain and Hudson valleys are connected by three narrow defiles beginning on the west with that of Lake George; next east comes that of the southern end of Lake Champlain via South Bay; then that of the Wood creek depression. These depressions, evidently preglacial, have been more or less modified by glacial erosion and deposition. For a time after the ice disappeared from these defiles, water appears to have stood over all but the highest of the cols (Harrisina hollow), on the eastern base of French mountain at the southern end of Lake George.

Lake George. The narrow valley occupied by Lake George is heavily choked with glacial drift at the southern end. The deposits from the ruins of old Fort William Henry southward along the old military road past Bloody pond bespeak deposition in front of a mass of ice filling the lake valley. Subsequent waters appear not to have risen as high as Bloody pond, a kettle hole in the drift, at an elevation of nearly 570 feet above sea level. The more open pass at the east base of French mountain appears to have been the line of the main preglacial valley. This pass is called Harrisina hollow on Fitch's map of 1850. There are here two apparently water-swept passages one at 393, the other at 349 feet in elevation.

Professor Kemp has called attention to the islands in Lake George as indications of an old divide, from which he infers that a stream once flowed north in the northern part of the lake and one south in the southern part, glacial deposition at both ends having brought about the existing ponding of the waters.

In the diagram, plate 28, it will be seen that the upper stages of glacial waters in this area following the retreat of the ice entered the northern part of the lake but the Harrisina channels could not have controlled the hight of any but those preglacial lakes which may have existed in the Lake George valley prior to the melting out of the ice from its northern end, for the reason that lower passes exist to the east in the Whitehall district.

No detailed examination of the valley was made in the present survey either for the history of the ice retreat or for shore lines.

Wood creek valley. The singular trench from Fort Edward to Fort Ann, alluded to on page 77, forming an extension of the Hudson river main trough has already been described. At its northern end it is continued by the valley of Wood creek into union with the Champlain valley at Whitehall. The drainage in both these swampy valleys is now northward into Lake Champlain.

Asa Fitch[1] ascertained, at the time of the construction of the Champlain canal through the Wood creek valley, a number of details concerning this swampy tract which are here stated in his words.

On excavating the Champlain canal, it was found that all along the valley of Wood creek, at about 6 feet below the surface was a layer made up of leaves, nuts, sticks, and logs, from whence springs of clear water were everywhere issuing. The nuts were plainly butternuts and beechnuts. Ash and other logs, quite sound, occurred, but no pine. Pine was originally abundant on the uplands each side of this stream, but none grew down in its valley. The trees, in most instances, it was plain to see, had their tops towards the south, that is, upstream. Below this layer of vegetable matter was a stratum of tough blue clay; above it was sand and loam, and in excavating for the bed of the canal lock 11 feet beneath the surface, the trunk of a black ashtree 2 feet in diameter, and somewhat decayed, was come upon.

A most important fact in this statement (continues Fitch) is that *these buried trees were mostly found with their tops towards the south, showing that when they were lodged here, the current was running in a direction the reverse of what it now does.*

One mile north of Fort Ann, Wood creek enters the highland region bounding the Fort Edward plains on the east, there plunging into a narrow gorge to pass into a constantly widening valley to Whitehall. This valley is of preglacial date at least with reference to the last ice advance but whether of Prepleistocene date in its restricted portion near Fort Ann is not now definitely known. Through it at Fort Ann the ice swept from the northeast as the striae south of Battle hill indicate.

Throughout the extent of this valley the clays which appear in Hartford and Argyle as well as in the low ground about

[1] A Historical, Topographical and Agricultural Survey of the County of Washington. Assembly no. 175, 1850. p.879–80.

Kanesville appear clinging to the sides of the valley in protected coves as high as the 240 foot contour in the vicinity of Comstock and westward. It is evident that these clays have been extensively eroded. In the stream valleys this removal may be attributed to the streams now flowing in them but in numerous cases along the sides of Wood creek valley the removal of the clays has been accomplished in a manner unaccounted for by stream action. These coves are repeated on the western shore of the southwest arm of Lake Champlain in the same series of deposits. The best explanation of them which I have arrived at attributes them to the sliding out of the clays in the manner of the land slips described by the late Dr G. M. Dawson[1] on the clay lands bordering the St Lawrence.

The occurrence of the coves on the western sides of valleys is in part explained by the sweeping away of clays by ice action along the eastern wall of the same valleys against which the ice sheet must have pressed with greater force. This admission of the greater age of the clays is in line with the eroded forms which the deposits assume from Kanesville southward to and below Fort Edward in the axis of the long trough before described.

Northward extension of clays into Champlain valley. The clays of the Wood creek valley, seen in Whitehall and about the northern base of Skene mountain are traceable into the Champlain valley proper. At Dresden Center the clays rise to 360 feet at least above sea level. Bodies of the clay occur in all the recesses of the narrow river valley or southern part of the lake as far north as Ticonderoga, where they are found as high as 400 feet above sea level.

No marine shells have so far been produced from these clays in this southern part of the Champlain valley or southward over the Fort Edward district. Numerous small and irregularly formed concretions are seen in the clays, and are sometimes reported by the inexpert as shells.

[1]Geol. Soc. Am. Bul. 1899. 10:484–90. Remarkable Landslip in Portneuf County, Ontario.

Chapter 7

DELTAS AND SHORE LINES OF THE CHAMPLAIN VALLEY

The deltas of the Champlain valley have been studied by the Vermont geologists and later by Taylor, G. F. Wright, Baldwin and Upham. The shore line phenomena of the New York side particularly have received mention in the literature. Mr Gilbert in his unpublished notes and Cushing in his report on local geology appear to be the first to recognize their distinctness particularly in the northern part of the area where the valley is wider and waves either of the sea or of a glacial lake would have had a greater fetch than in the southern constricted portion of the lake.

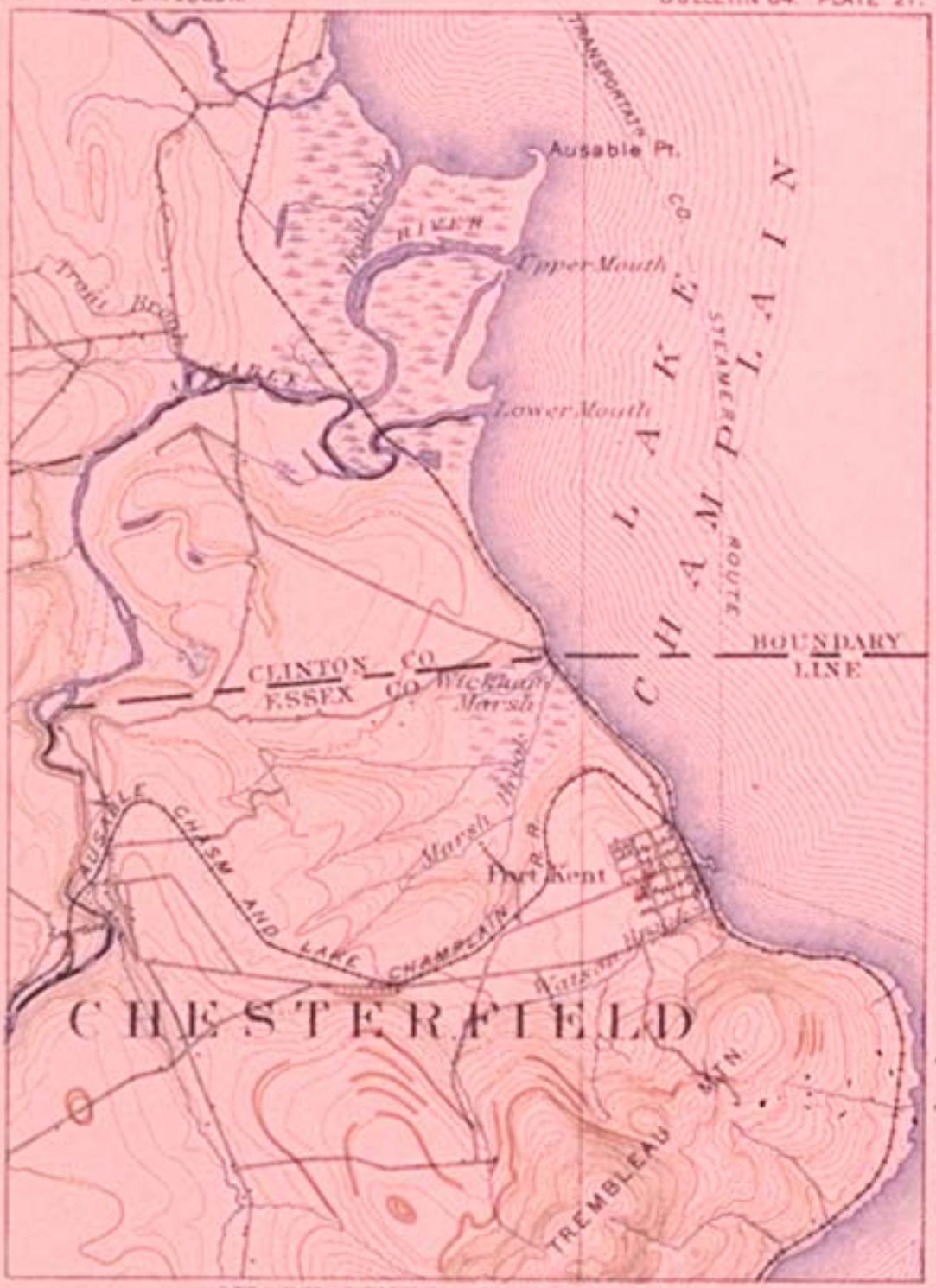
From near Ticonderoga something like beaches begin to become recognizable in favorable situations and gradually increase in size and distinctness toward the northern part of the State till within a few miles of the international boundary where they become here and there striking objects.

Space can be found for the description of types of these deposits only and then mainly the highest occurrences seen.

Parallel roads on East Bouquet mountain. Immediately west of Bouquet station on the Willsboro quadrangle rises East Bouquet mountain, a rounded hill attaining an elevation of 1225 feet. On the northeast slopes of this hill signs of wave action are traceable about halfway to the top. As nearly as I could estimate my position on the uppermost of these marks by the contour lines of the map, the highest of these wave lines is at 570 feet. The plane of tilting between the highest wave marks on Trembleau mountain and the Street Road highest beach cuts this hill at 560 feet, which is presumably a better reading than 570 feet [*see* pl. 28 and explanation].

Port Douglas beach ridge. On the Willsboro quadrangle, south of Trembleau mountain, a foothill of the Mt Bigelow mass is formed by a relatively thick drift deposit in the form of a ridge overlooking Corlear bay. The crest of this ridge, contoured to 540 feet on the United States Geological Survey map, is wave heaped with subangular cobbles. This ridge must have formed an offshore bar or shoal when the waters stood at its hight over the Cham-

PART OF THE PLATTSBURG QUADRANGLE



SHORE LINES AT PORT KENT.

Scale $\frac{1}{62500}$

0 1 2 Miles

Contour interval 20 feet.

Datum is mean sea level.

Beaches and wave cut lines

Cliff in till with base at upper marine limit

Fossil marine shells

plain valley. I have taken the level from the local contour of the Willsboro quadrangle.

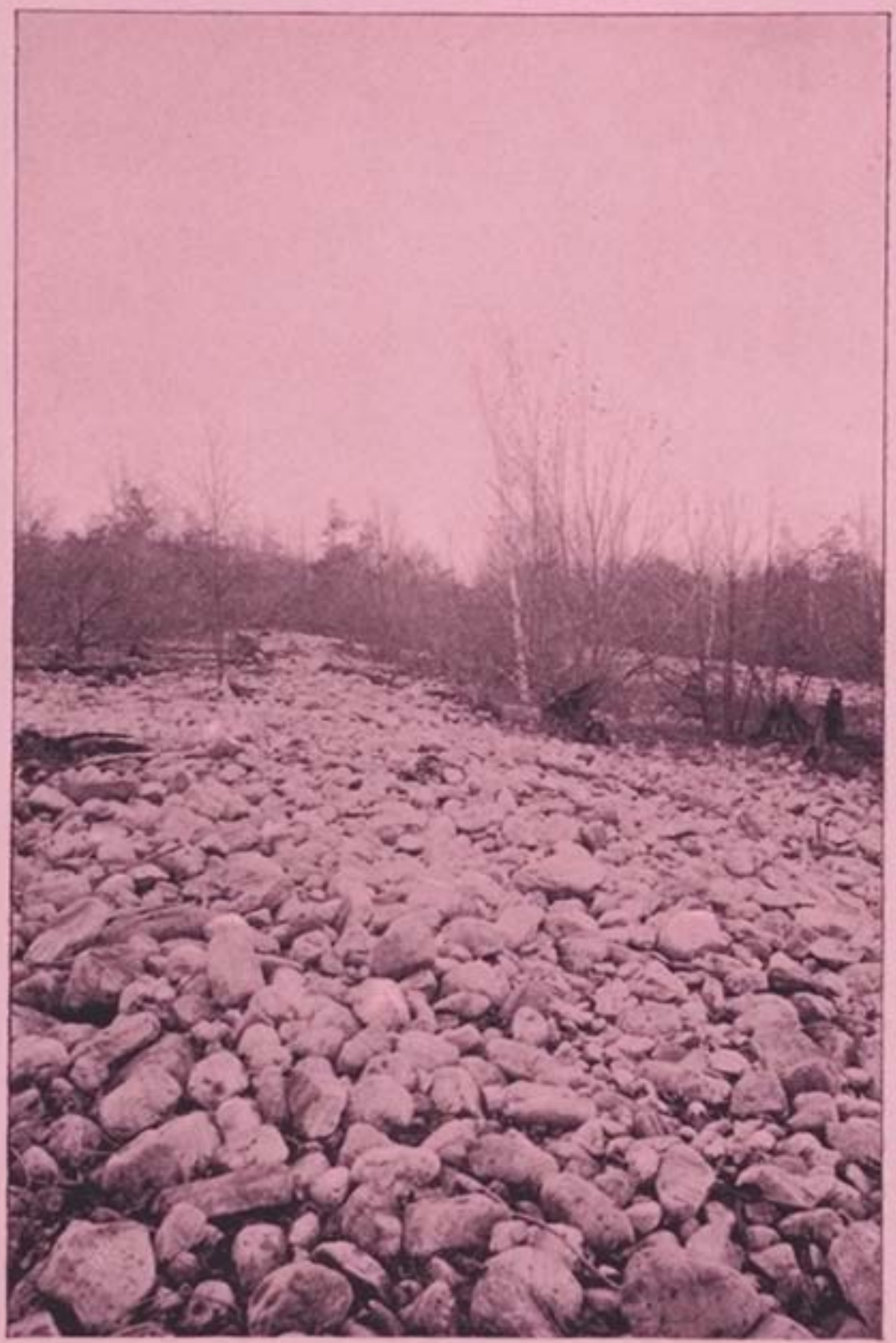
Shore lines and deltas about Port Kent. By reference to the topographic map, plate 21, giving a part of the Plattsburg quadrangle, it will be seen that shore lines and deltas are to be found from Port Kent back to Keeseville on the Ausable river.

Trembleau mountain on the south is thinly covered with drift particularly on the lakeward slope from 500 feet downward. Much of the steeper slope immediately west of Trembleau point has been stripped of drift by wave action. Heavy till deposits farther inland occasion the northern slope in the form of the broad spur extending from the 600 foot contour line down to the 400 foot line. Till again appears near the lake shore in Port Kent village; though on top of the hill on the border of the streets as laid out on the map a well was sunk some 12 feet in coarse waterworn materials containing cobblestones up to 10 inches in diameter, probably waveworn materials.

Shore lines begin to appear first, as one descends Trembleau mountain, at about 590 feet. The deposits of this stage suggest the presence of ice, either floating or pan ice, by reason of the angular blocks in the rude but essentially horizontal, often spitted, beachlike deposits which can be traced where shown by the line on the map. Definite wave-heaped beach ridges appear a few feet lower at probably 580 to 585 feet in the elliptic hill crest shown on the map. The stones are subrounded in this deposit inclosing a shallow saucer-shaped depression in the center—the old lagoon of this offshore wave-heaped shoal. From this level traces of wave marks in parallel roads or occasional lines of waterworn pebbles (as along the road from Port Kent to the lowest notch in the crest of the mountain) appear down to at least the levels of the two churches in Port Kent.

Near the old tollgate site, 1½ miles west of Port Kent, the spur of till before mentioned is cut back in the form of a good sea cliff having a length of about ½ mile. The base of this cliff is at about 340 feet and is confronted by one of the delta levels of the Ausable. It would appear that the heaviest and longest wave action took place locally at this level. That the escarpment in the till is due to wave cutting rather than to stream cutting during the

Plate 22



View looking north along the eastern slope of Cobblestone hill, just below the crest

retreat of the ice sheet is shown by the fact that the surface of the till spur above this level is deeply cut by what I take to be marks of wave action. Well rounded gravel is encountered at approximately this same level farther east on the northern face of Trembleau mountain, indicating efficient wave action there sufficient to pocket the material between ledges.

There is a noticeable grouping of shore lines in Port Kent between 200 and 260 feet; back of Port Kent about 350 feet; a rather persistent shore line at or just below 500 feet and in favored situations from 500 up to 585 feet. The most marked wave action in this range is at 350, 500, and from 585 to 590, because these last are the highest seen. A search above the 600 foot line over the top of Trembleau mountain failed to show higher signs of wave action.

A 500 foot delta plain is extensively developed about Keeseville, both east and west, and to the south as well. About 1 mile northeast of Keeseville, a hillock rises up on the sloping surface of the delta plain with what appears to be a circular shore line as shown on the map. The strength of the delta building and that of the shore line at the 500 foot line are rather marked.

The next marked delta stage in descending order coincides with the base of the cliff above described at about 340 feet. A fragment of delta terrace lying between Wickham marsh and the Ausable, having a surface at about 250 feet elevation, accords with the wave lines in Port Kent village.

As noted on the diagram, plate 28, these shore lines and deltas appear to be correlated with a tilted series of strong and weak lines of wave action and deltas traceable southward from the international boundary. It is probable, as I have attempted to show in chapter 10, that the upper marine limit at Port Kent is found at about 340 feet. Delta building at this stage would have covered the Ausable chasm; hence, it follows that the chasm must have been cut since the land began to rise from the marine limit.

Fossil marine shells have long been found in the sands of the delta south of Port Kent station. An account of these shells will be found on page 212.

Shore lines at Harkness. At Harkness on the hill east of the railroad station there is a beach ridge at about 500 feet (aneroid). This hill has a northeast exposure. A small stream entering the valley just east of the station has a sand delta at 510 feet. Above this delta on the hillside there is a faint shore line at 550 feet. Going up a gully excavated in gravel and sand and coarse cobbly drift, one comes to the top of an earlier deposit of the stream at about 650 feet. Above this level to 675 feet is a till ridge with kamelike contours.

Below Harkness on the east of the railroad and at the foot of Hallock hill a sandy ridge extends for 2 or 3 miles at about 380 feet elevation. The materials appear to have been wind blown.

Deltas of the Saranac. There is a heavy development of deltas along the course of the Saranac river specially between Plattsburg and Cadyville. Unfortunately this district immediately west of Plattsburg has not yet been mapped topographically.

There is a high level glacial delta just east of and below Cadyville station (732 feet) with associated kames indicating deposition in the presence of ice. Baldwin gives the elevation as 729 feet. This corresponds with a series of sand plains in the valleys west of Lake Champlain if we admit a tilting essentially parallel with that of the upper marine limit. This tilted level correlates with the bare rock spillway southwest of Schuylerville from near Quaker Springs toward the battlefield of Saratoga. The waters in these northern side valleys must have flowed along the ice margin with slight fall toward the south where a lake appears to have existed at least over the Fort Edward district.

Below this high level delta about 40 feet is another level as yet not well understood. At about 650 feet there is a large sand delta which appears to be correlated with the tilted water plane contemporaneous with the Coveville stage of the glacial lake which covered this district.

Again at Morrisonville station (449 feet) there is a broad plain at about 450 feet above the sea which appears to be correlated with the uppermost of a crowded series of beaches which extend up to 540 feet at the international boundary and decline southward. It was probable that at this time the waters did not discharge southward through even the lowest of the channels near Fort Edward

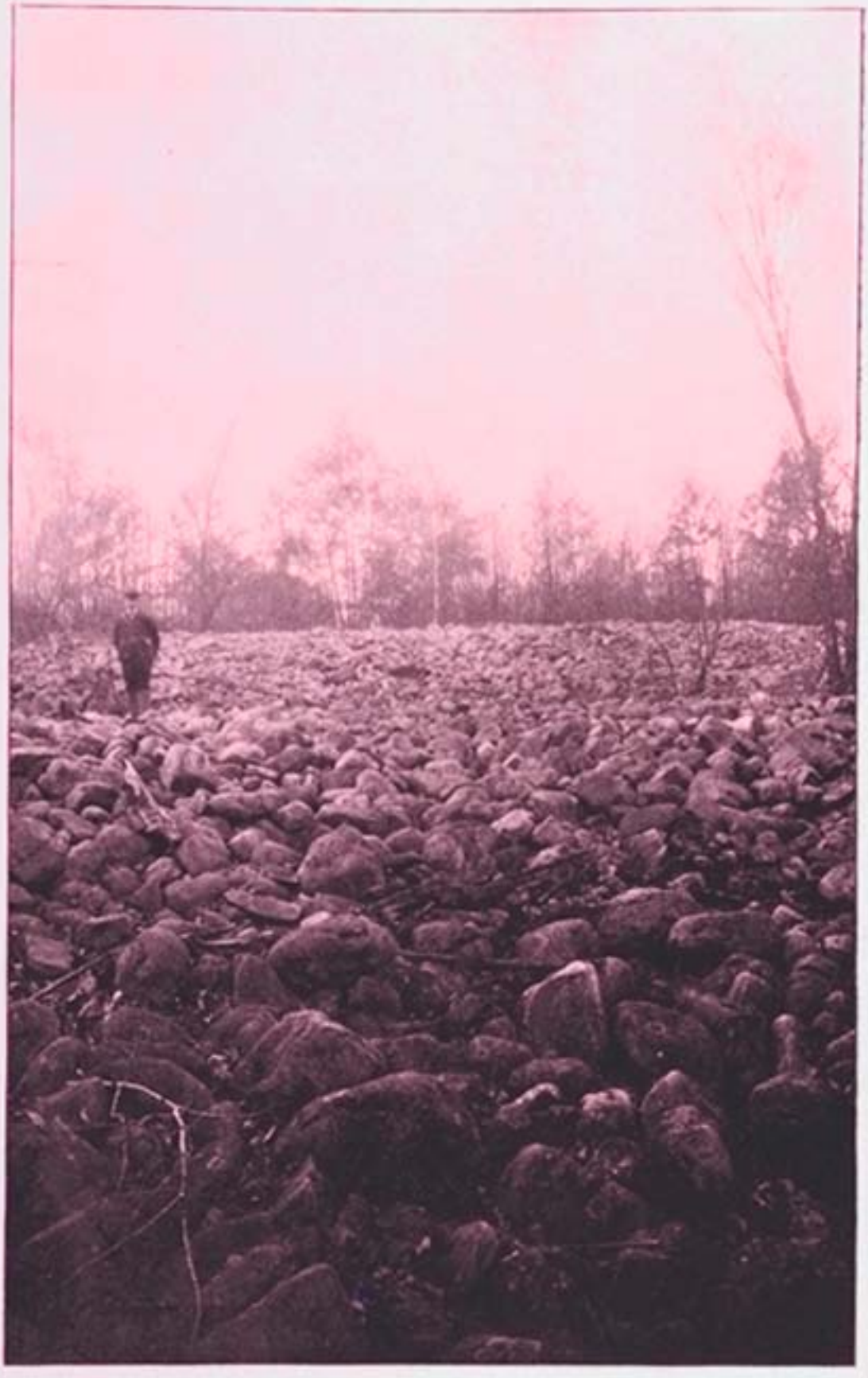
but if they were not at the sea level of the time, formed a stage of the glacial lake in which a discharge was found past the northern border of the Green mountains into the lower St Lawrence valley past the edge of the ice sheet. This is a point however which is still under investigation.

In the lower margin of this delta at Freydensburg's mills at an elevation of 340 feet marine shells have been found. There are slight topographic evidences that this portion of the deposit is separated constructionally from the broad plain at Morrisonville. Certainly this part of the deposit was made in the sea. The calculated hight of the upper marine limit at this locality is 375 feet.

Shore lines of the Mooers quadrangle. The shore lines and deltas of this area are more fully described in the special report on that atlas sheet.

Beginning on the south near West Beekmantown, there are faint traces of wave action up to nearly 640 feet. Occasionally stronger traces with definite beach ridges are found at higher elevations northward till Cobblestone hill, northwest of West Chazy [*see* pl.22] is reached when remarkably strong wave action is found as high as 675 feet [*see* station 50, pl.28]. Thence northward beach ridges occur along the northern and eastern margin of the Altona flat rock district at a slightly increasing elevation toward the north. There is a delta at Altona [*see* station 51, pl.28] with what appears to be an ice-free margin at 640 feet, and the remnants of another on the north branch of the Big Chazy river at an elevation of at least 660 feet [*see* station 52, pl.28]. North of Deer pond there are faint shore traces at about 705 feet. At Cannon Corners on either side of the English river there are hook-like bars curving into the valley mouth between 700 and 720 feet in elevation. Somewhat south of these and on the extreme western border of the area what appear to be wave-heaped materials occur as high as 750 feet. In the extreme northwestern corner of the quadrangle at the head of Kellas brook in the region known as Armstrong's Bush there is a cobblestone ridge with a recurved hook at its southern end at an elevation of 720 feet [*see* station 53, pl.28]. A short distance west of this last example at the corner of the road leading to Covey Hill postoffice and beyond the limits of

Plate 23



The crest of Cobblestone hill, showing strong wave action on boulders and large cobbles. Looking west. Elevation about 650 feet

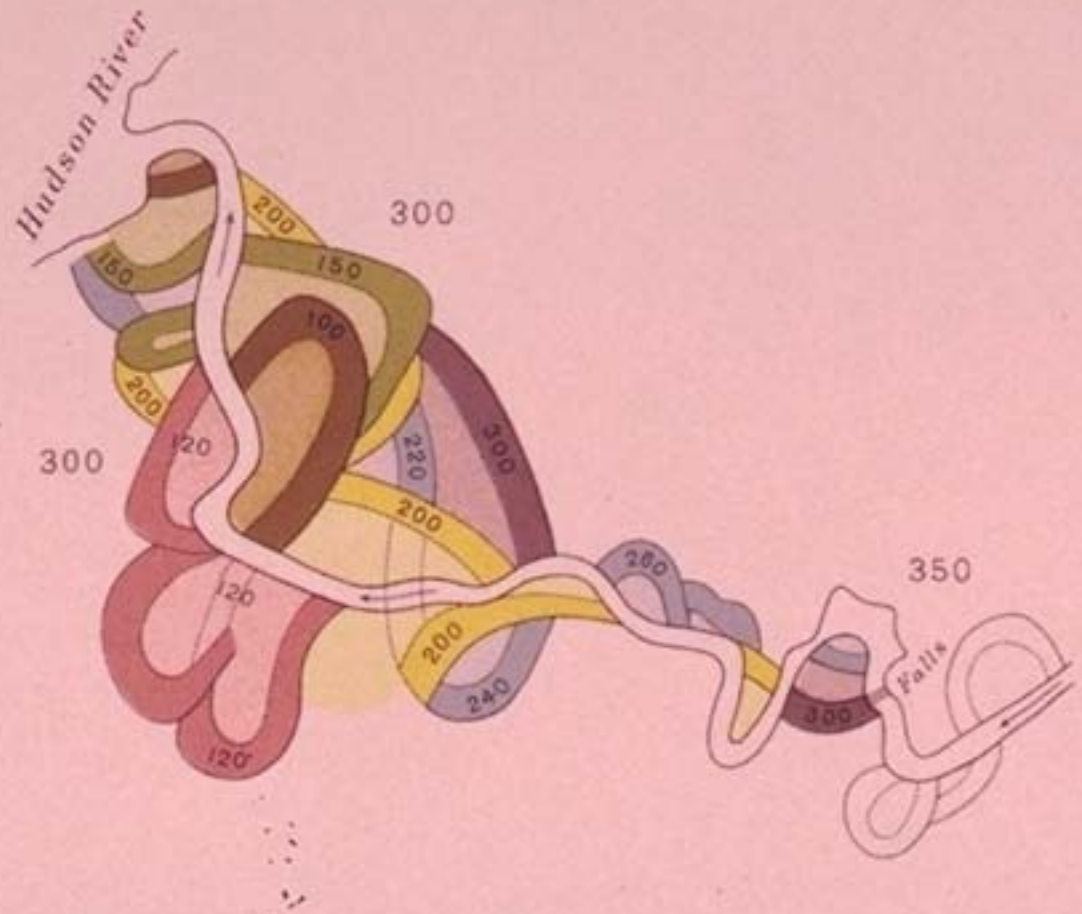
the map [pl.29] there is a similar cobblestone ridge at about 800 feet elevation (aneroid). Over all the northern half of the quadrangle these isolated deposits are separated by an interval of about 100 feet from the next high mark of wave action, beginning the record along the international boundary at about 620 feet. In the southeastern half of the sheet, wave-made traces are visible from the top of Cobblestone hill down to the low ground on the east of the area.

Beginning on the international boundary in the region of Armstrong's Bush, wave-heaped materials begin to appear at about 540 feet in a closely crowded series of ridges of angular shingle extending down to about 360 feet. Southward the upper limit of this group falls off in elevation and in the vicinity of Wood Falls on the Big Chazy the highest clear beach is found at 500 feet. In the southern part of the sheet this lower series is not distinguishable from the upper series in any manner which I have been able personally to devise.

The accompanying map [pl.29], shows the location and extent of the more distinct traces of these and other beaches.

Shore lines about Covey hill, Canada. Reference has already been made to the occurrence of a well defined beach taken by Mr Gilbert to be the upper marine limit on the north side of Covey hill at an elevation of 450 feet [*see* p.162]. On plate 25, I have attempted to delineate the position of this beach for a portion of its extent. It is a very strongly developed beach for this district with well worn pebbles on its seaward face. Below it occur others toward Ste Antoine and Vicars. Accepting the terraces which come above this beach as made by waters escaping along the ice front, this 450 foot beach is the highest one found to extend from the beaches of the Champlain valley around the northern face of Covey hill. Its westward extension is known at a number of points near Sun, East Constable, Potsdam and places still farther westward. But in the district southwest of Malone the ground becomes so much broken up in the form of short hills that tracing it is difficult without a good topographic map as a guide to localities in which wave action should be looked for.

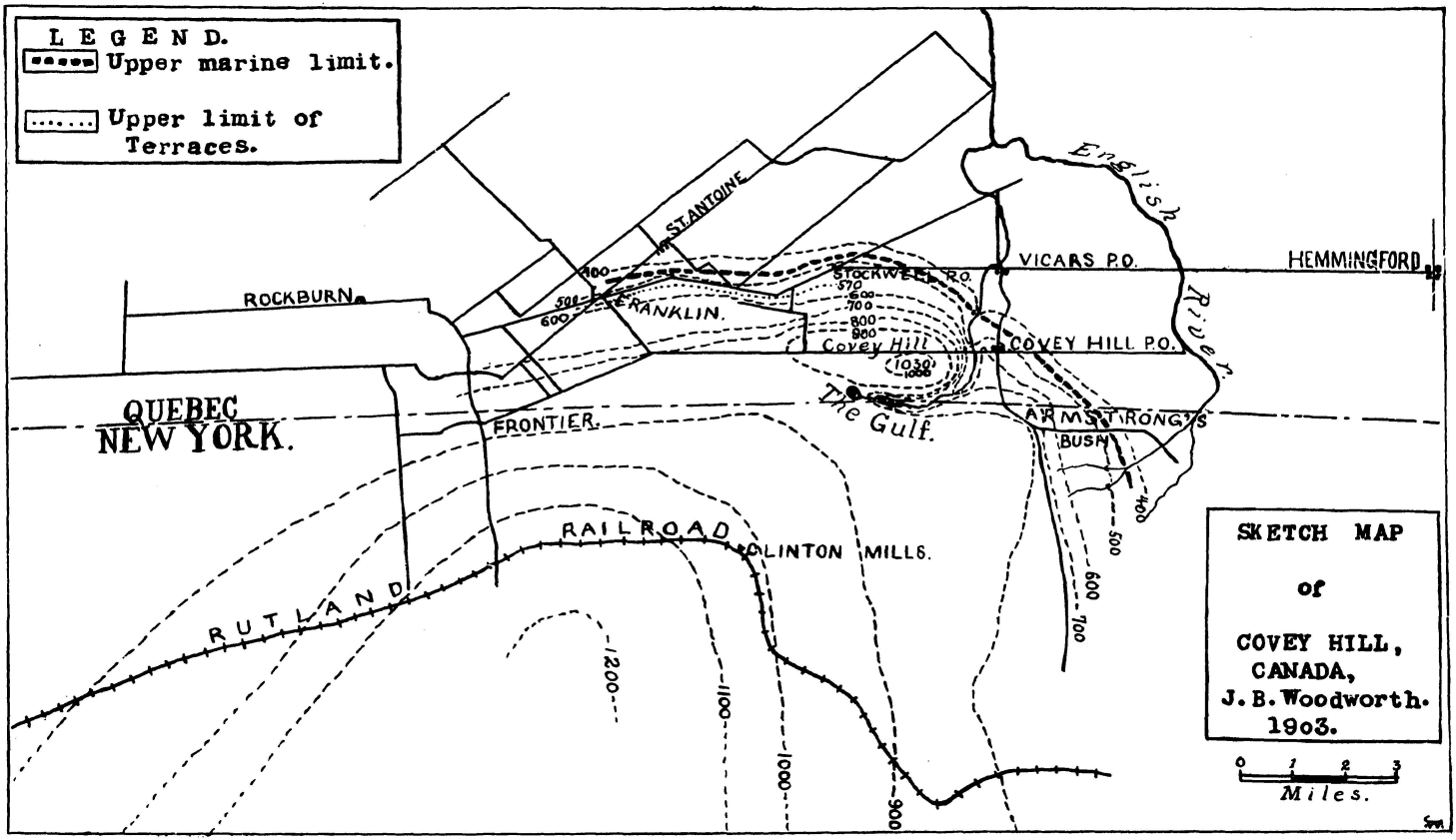
The vicinity of Covey hill is of critical interest in the solution of the problems relating to all the shore lines of the Champlain

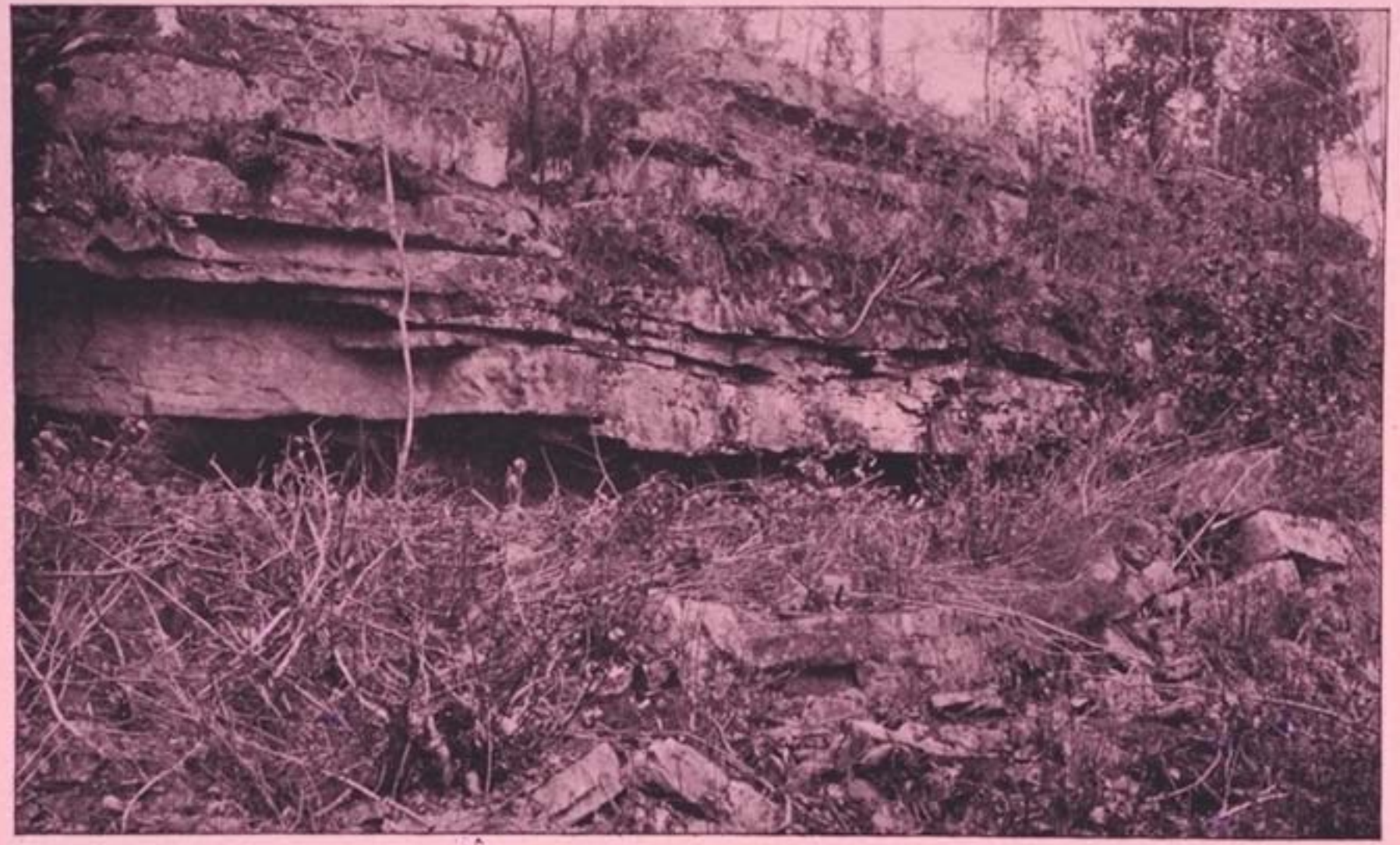


SCHEME OF TERRACES IN DELTA OF THE HOOSIC.

and upper St Lawrence valleys. Any refinement or revision of the problems with which this report mainly deals should be begun at Covey hill. The absence of definite shore lines on the smooth till slope of the northern face of this eminence from 570 feet to the top is in striking contrast with the wave-ribbed slopes of the Champlain valley on the south at an equal elevation. Except for one or two faint traces of parallel roads and a small delta on the north slope at an elevation not far from 800 feet the till slope of the upper half of the hill is practically as left by the ice sheet. The failure of beaches and cliffs due to the work of waves in this upper zone just where waves would be most effective had an open body of water been present to transmit the undulations of its surface against this impressionable glacial coating is one of the most conclusive arguments for the theory of glacial barriers. I have already described the corroborative evidence as to the upper limit of standing water in glacial lakes found in the abandoned spillway and waterfall of the Gulf.

Plate 25


LEGEND.
Upper marine limit.
Upper limit of Terraces.
ROCKBURN
QUEBEC
NEW YORK.
FRONTIER
FRANKLIN.
ST ANTOINE
STOCKWELL P.O.
VICARS P.O.
HEMMINGFORD
COVEY HILL P.O.
Covey Hill
(1030)
The Gulf.
English River.
ARMSTRONG'S BUSH
RAILROAD
CLINTON MILLS.
RUTLAND
1200
1100
1000
900
800
700
600
500
400
SKETCH MAP
of
COVEY HILL,
CANADA,
J. B. Woodworth.
1903.
0 1 2 3
Miles.



Upper part of the old cliff south of Sciota shown in plate 13

Chapter 8

LARGER GLACIAL LAKES OF THE CHAMPLAIN AND HUDSON VALLEYS

LAKE ALBANY

The preceding descriptions of the successive stages of frontal and marginal deposits of the shrinking ice sheet and the attendant evidences of local water bodies within the Hudson valley make it evident that as the ice front retreated from the terminal moraine, bodies of water stood at the ice front increasing in length northward as the ice withdrew in that direction. Doubtless at many of these stages the water in front of the ice might justifiably be denominated a lake regardless of the relation to sea level. If the land were at the same level as now the outpour of fresh water would have excluded the salt and made the conditions those of an estuary or lake; with the land 100 feet lower so as to bring the deltas and terraces at Peekskill south of the Highlands at sea level the same conditions would have held; if for any geographic reason the entire southern Hudson valley were above sea level at that time lacustrine rather than estuarine conditions would have prevailed. These considerations hold good also for the conditions in front of the retreating ice sheet as far north as the vicinity of Poughkeepsie at least. But north of Staatsburg and thence northward throughout the Hudson valley there is a record of continuous lacustrine conditions for a time marked by beds of clay and marginal deltas which indicate typical lacustrine conditions in the total absence of marine fossils from the beds deposited at this time. To this body of water whose clays were early designated the "Albany clays" by Ebenezer Emmons, no name is so appropriate as Lake Albany.

E. Emmons[1] wrote "the Albany clay, or as it is in other places called Post-tertiary clay," in 1843, long antedating the name Albany as used in the geology of Texas.[2] He regarded the clays

[1] Natural History of New York, division 5, Agriculture. 1846. 1:260.
[2] U. S. Geol. Sur. Bul. 191, p.42.

and the sands which overlie it as one formation. According to him the chemical composition of the clays is as follows:

Water of absorption	4.25
Organic matter	1.17
Sulfate of lime	1
Silicates	69.02
Peroxid of iron and alumina	17.24
Potash	.14
Carbonate of lime	4
Magnesia	3
	99.82

A trace of chlorid of sodium exists. No exact statement of the source of chlorid of sodium in this clay can be given. If it were marine it would be expected that considerable traces of common salt and other sea salts would be found. The trace of chlorid of sodium noted by Emmons has no bearing on the marine origin of the clays since such traces are found in the surface waters even of the Berkshire hills.[1]

Mr Asa Fitch M. D.[2] employed the term "Albany clay formation" in 1849. He stated: "As neither its geological age or name is well settled, I prefer designating it the Albany clay."

Mr Fitch[3] noted the essential continuity of the clays from the Hudson valley to Whitehall and thence into the Lake Champlain valley. In most of Washington county the clay rests directly on the Hudson river slate, though extensive beds of gravel locally intervene. East of Comstock's landing the clay is stated to be 20 or more feet thick. In a railroad cut across the river from Fort Edward, Mr Fitch noted sand layers alternating with clay with local unconformity between these beds and an overlying sand deposit containing boulders of the underlying clay beds.

Lake Albany doubtless began on the south in the waters standing in front of the retreating ice sheet prior to the opening of

[1] *See* Mass. State Bd of Health, 23d Rep't, with map. Boston 1892.

[2] Historical, Topographical and Agricultural Survey of the County of Washington. N. Y. State Agric. Soc. Trans. 1849. 1850. 9:872.

[3] *l. c.* p.873-75.

the Mohawk outlet of the great glacial lakes on the west. As soon as the ice retreated in the valley to a position north of Albany and the drainage of Lake Iroquois came into the Hudson valley Lake Albany properly came into existence.

The clays, and the deltas marginal to them, extend north of Albany certainly as far as the Moses kill. At this place the Hudson gorge proper widens out and the Albany clays which mantle the rock terrace marginal to the gorge are separable from the clays of the low grounds northward by reason of the partly ice-swept character of the surface apparently indicating that the northern limit of the lake was at one time formed by an ice margin over the Fort Edward district. That Lake Albany with the melting out of the ice from the Champlain valley became confluent with the glacial lake stages of that district is borne out by the extension of clays from one region to the other and by the extension of the water levels of the Lake Champlain area into the upper Hudson valley through the Wood creek pass.

The shore line of Lake Albany is most clearly shown by the altitude of the deltas of the larger streams which emptied into it. These include the old delta of the Mohawk, that of the Hoosic and the Batten kill and numerous smaller deposits southward in the Hudson valley. I would refer to Lake Albany only those deltas which appear to have been built in open water between the Batten kill and the vicinity of Rhinebeck. South of the last named point the deltalike deposits adjoining the Hudson gorge appear to have been built in front of the retreating ice sheet, and I am led to think that the surface of these proglacial deposits was mainly if not altogether above the level of Lake Albany at the time of its maximum development, the waters escaping from the flooded middle Hudson valley through the old gorge on the south as waters now escape but perhaps at a still greater depth owing to a higher stand of the land on the south.

It will be observed that the deltas on the eastern side of the Hudson valley from the Batten kill northward to the Poultney fail to coincide with any one plane. In a report of progress on the field work for 1900 I interpreted the falling off in altitude of the deltas successively northward from that of the Batten kill when compared with the highest shore lines about

Ticonderoga as due to a warping of the crust in the postglacial changes of level.[1] A more complete study of all the phenomena involving a correlation of the spillways about Schuylerville with delta and shore lines far to the north makes it more reasonable to suppose that these lower deltas on the north of Schuylerville were deposited in succession in the falling water levels of a glacial lake with varying but successively lower outlets lying between the site of Fort Edward and Stillwater. In this view these lower deltas were not made in the waters of Lake Albany. If Lake Albany extended northward over the Fort Edward district and connected through the passes of the mountains with the Champlain valley, its deltas should be found successively higher on the north somewhere near the altitude of the line of comparison on plate 28. Thus on the Fort Ann quadrangle the valley train of gravel and sand in the Mettawee valley above Raceville and about Middle Granville lying above the 400 foot contour line if not deposited at the Lake Albany level was at least laid down in these side valleys in probable contemporaneity with the later northern phase of this lake. There is a corresponding terrace on the western side of the Hudson valley at the base of Palmertown mountain, evidently an old delta of the Hudson but probably made in the presence of ice remnants in the valley though positive proof of this is now wanting.

Of shore lines, between the deltas there is no distinct sign of wave action though along the eastern side of the valley a few feet above the upper limit of the main body of the clays there is a zone of smoothened and straightened contouring of the ground, above which unmodified drift surfaces present a noticeable contrast. This kind of evidence is most marked from the Moordener kill northward past Troy to the Batten kill, a line which coincides very closely with the inner and upper margin of the old rock bench of the Hudson valley floor.

Correlation of Lake Albany with the western great glacial lakes. Lake Albany received on the north in the portion of its extent lying within the upper Hudson valley several large streams, the Moordener kill, Hoosic river and the Batten kill, coming from the east; on the west, the Adirondack–Hudson for a time at least, and more than all the drainage of the Mohawk valley.

[1] N. Y. State Mus. An. Rep't. 1901. p.r13.

The large delta of the Mohawk extending from Schenectady toward Albany is a witness of the fine sands and clays which poured into Lake Albany from the west, in which direction lay the great glacial lakes whose development coincided with the retreat of the ice front across the Mohawk valley. The stage of the great glacial lakes with which the delta appears to be equivalent is that of Lake Iroquois with its outlet at Rome and thence draining into the Hudson valley.

Conditions under which the Albany clays were deposited. The conditions under which gravel and sand are deposited both above and below the level of standing water are much better understood than is the case with the sedimentation of clays, particularly those deposits with which we are here concerned, the rock-flours of glaciated districts. At the present time, there is an abundant literature concerning the clays of existing and vanished glaciers, in which, however, there is scant discussion concerning the factors which control the deposition of clays.

There is a variation in the delivery of clay from a glacier dependent on diurnal and seasonal changes of temperature in the atmosphere, subject to modification by the passage over the glacier of those whirls of the atmosphere known as cyclonic movements or storms with their accompanying precipitation in the form of rain or snow.

Diurnal changes of temperature and their effect on glacial clays. With each rotation of the earth on its axis in middle latitudes, a glacier is alternately exposed to the sun's heat and shielded from this cause of melting. During the day, the effect of insolation is to swell the glacial drainage with water carrying detritus set free by the melting of the ice. Other things being equal a larger quantity of clay will be carried out of a glacier at day than at night when the streams are checked. The greater volume and velocity of the streams discharging directly from a glacier into a water basin during the day will tend to carry the suspended clay particles farther out and allow of their wider distribution by stream-made currents than at night when not only is there less clay delivered but the transporting agencies are less effective. But the clay deposited under these day conditions will contain more coarse mineral particles than the night clays when only the finest rock-flour escapes to the area of clay deposition. There

may thus arise a banding of the clay deposits, in which coarser, thick rock-flour layers near the ice margin represent day additions and thinner, finer, more unctuous clays represent night deposits.

The control thus exerted will be confused or lost where the waters discharging from different ice fronts reach the area of clay deposition through a common distributer after journeys a half day's stream travel in difference of length. In this case, the day discharge of one stream may deposit at the same time as the night discharge from another stream. A similar disturbance or nullification of the differences of day and night discharge must take place in the Rhone valley where tributary glacial streams at varying distances from Lake Geneva have their clay load delivered to the lake several days after the start of the journey. Where the clay load of day discharge from one glacier near the head of the Rhone passes a tributary fed by a glacier lower down the valley at night, the day load of one becomes mingled with the night load of the other; and thus the difference between day and night conditions in glaciers which do not discharge immediately into clay-depositing areas will not have their diurnal changes recorded in the clay areas to which they contribute. As regional glaciers draw their frontal discharge of water from longer distances than valley glaciers such as those in the Alps, it is probable that there will be less difference between day and night discharge at the front in the former than in the latter, for the reason that some of the day water of the inland ice may reach the front only after half a day's journey, thus tending to equalize the outflow. For all these reasons, it is probable that except in the case of the discharge of a single glacial stream into a limited area of clay deposition, diurnal changes of temperature will exert little control over those variations in clay laminae which are characteristic of glacial rock-flours.

Annual change of temperature and its effect on glacial clays. Summer is the time of glacier melting, winter the time of arrest of melting if not of actual freezing of glacial waters. The summer discharge of glaciers is prevalently pebbly and sandy; the winter discharge is prevalently clayey, for the streams may not then be vigorous enough to carry sand and pebbles out to the

depositing grounds. Emerson[1] has invoked this seasonal change to account for the alternate lamination of bands of fat and lean clay in the Connecticut valley, making each layer of lean clay correspond to a summer, and each layer of fat clay to a winter.

It is difficult to see how either this or the preceding variation in clay discharge will account for the essentially even deposition of alternately coarse and fine layers of clay and particularly alternations of layers of clay with layers of fine sand over a large area of deposition far from the mouth of the discharging streams, for the fine sand would go to the bottom within a short distance of the edge of the water basin where the streams entered.

Astronomical changes. Gilbert, noting the remarkable rhythmic succession in the alternation of clays and sands in certain sediments of the West compared the phenomenon with the supposed effect of periods of minimum and maximum variations in the ellipticity of the earth's orbit, the geologic effects of which were first pointed out by Sir John Herschel. But as the period of such maxima and minima in the theory proposed by Croll correspond to entire periods of glaciation and deglaciation, it is not to be supposed that the glacial clays of a single episode of deposition manifest any control exerted by these changes and we may therefore dismiss the view as having no bearing on this group of clays.

Prodelta clays. There are several other conditions controlling or interfering with the deposition of clays, particularly in bodies of water lying within or adjacent to a retreating ice sheet. One of these conditions is inherent in the method of delta construction by which a stream swings from side to side of its delta.

For illustration the simplest case will be taken, that of a glacier discharging its drainage by a single stream into the head of a bay or lake on the border of which it has already built a delta across whose surface the stream swings in the process of discharging its load of gravel, sand and clay.

While the stream is aggrading its delta, it swings from side to side through the arc whose trace is the free margin or shore line of the deposit and whose center is the mouth of the glacial stream. Take the stream at a moment when it lies at one side (say the left) of its delta contiguous to the ice front. Its burden

[1] Emerson, B. K. Geology of Old Hampshire County, Mass. U. S. Geol. Sur. Monogr. 29. 1898. p.706–7.

of gravel and coarse sand enters into the construction of the delta proper. Over the bottom of the lake or bay the clays carried out in suspension are constantly coming to rest at distances from the delta margin determined by the presence and velocity of the currents and the time taken for the particles to fall through the water. For some distance over the bottom in the path of the stream-made current, the finer particles of sand which have not at once been drawn by gravity down on the delta talus will come to rest, forming a deposit of very fine sand extending outward from that part of the base of the delta. Around the remaining portion of the area confronting the delta base, clays will deposit as elsewhere over the floor of the water body. In the course of



Fig. 22 Cross-section of interstratified clay and sand on lake or bay bottom in advance of a delta

a few days or weeks or months, dependent on velocity, load, and the area of its delta fan, the stream will have moved laterally across its delta to the opposite side. The fine sands will now have been deposited over the entire area in front of the delta base while clays will have been deposited on that side where sand was previously going down. Still later, the stream will have swung back to the left of the delta and sands will be depositing along that portion of the basin floor, while clays are deposited over all the area on the right. The stream thus swings to the left and right of its delta, strewing fine sand over the bottom in advance of the delta. These changes will continue so long as the stream is building up its delta and the water body is unfilled with sediment. There will thus be built up on the floor of the basin an alternation of layers of clay and fine sand, whose stratification seen in a cross-section drawn transverse to the axis of the delta will be that shown in figure 22, in which the black line represents the sand layers, the white banding, the clays.

Where the stream halts, the sand layer will be thicker than where the stream has moved steadily along in its lateral motion. At the extreme right and left, where the stream has halted and turned back on its course, the sand bands should be thicker than in the middle of its shifts.

Sand partings will ordinarily be thinner than the clay partings for the reason that the fine sand is depositing over the basin only beneath the laterally shifting, stream-made current, while clays are making everywhere else in the longer time during which the stream fails to cover the much larger segment of the arc traversed by its swings. The thickness of clay layers and sand layers will be greater the slower the rate of lateral swinging of the stream; the sand layers will thicken toward the delta, the clay layers will thicken away from it; and at a distance beyond which the fine sand is carried in suspension, the deposit of clay will be from this cause alone continuous. The rate of lateral shifting will increase directly as the load carried by the stream since the excess of detritus left on the delta plain over that carried to its edge fills up the bed and causes the current to slide off on to the part not so much built up or to give off distributaries which will naturally start out from the side toward which the stream is shifting. Thus increase in load and marginal discharge will not give rise to a proportionate increase in thickness of the prodelta sand layers for the reason that the stream will not deposit sand for so long a time over a given space, because its cycles of swinging will be more rapid.

Delta streams tend to break up into minor streams or an interlacing of streams, so that there will frequently be many lines of prodelta sand deposition, introducing minor bands of sand and clay. The breaking out and shutting off of a distributary which ends independently on the delta edge will give rise to lenticular partings of sand over the prodelta floor.

The above statement is somewhat ideal, but the prodelta clays of the small esker fan at Drownville R. I. appear to the writer to illustrate the theory here presented. It is doubtful if the regular banding of larger bodies of clay miles beyond a delta margin with an even lamination of sandy partings can be so explained. The criterion of the applicability of the explanation to any given area will be found in the thickening of the sand partings in the direction of the delta and their passage into the segment of the "foreset" beds of the delta with which they are contemporaneous along any given portion of the delta front. Observation and experiment are required to determine the distance over which fine sands may be carried in suspension in fresh, salt and brackish water.

Another source of the variations in clay texture and a cause of sandy partings lies in the fine sand and dust blown out over bodies of water by the winds. Such subaqueous deposits it is believed are more widespread than has generally been supposed. The agency of the winds is readily recognized when the product transported is volcanic ash, but in the case of ordinary sands and rock dust it is less easy to determine the wind-borne origin of the material when laid down under water.[1]

The abundant evidence of the deflation of the sandy and gravelly plains left bare by the retreat of the ice in the eastern United States and the extent to which such sands are now being blown away from one tract and accumulated on another makes it highly probable that eolian deposits would be made in bodies of water and particularly in this latitude in the warm months of the year for during the winter snow and ice protect the sand from wind action. These sands in New England usually blow during the times of dry westerly winds, for the reason that easterly moist winds by the films of hygroscopic water which they permit to collect about the dust particles cause them to adhere and resist the action of the wind. These alternations of moist and dry conditions, of easterly and westerly winds, occur at the present time with singularly frequency owing to the movements of cyclones across the eastern United States. As noted by Clayton, rainy days with easterly winds recur about once a week and so do the following westerlies. Applying this possible cause of the interlamination of fine sandy layers with the glacial clays as they occur in the Upper Hudson valley, the clay layers would correspond to times of wet conditions when discharge from the ice would be most active; and the films of sand would correspond to longer or shorter episodes of strong westerly winds according to the thickness of the bands. In this view, the summer time of marked development of the interlamination should be distinguishable from the winter time of almost continuous clay deposi-

[1]For instances of wind-borne dust and fine sand showered down over water bodies, *see* Verbeck, Chevalier. Krakatoa and the appended charts; Reclus, E. New Physical Geography, vol. 2, The Ocean. N. Y. 1886. p.198–200; Darwin, Charles. Naturalist's Voyage Around the World. N. Y. 1887. p.5; Marsh, G. P. The Earth as Modified by Human Action. N. Y. 1874. p.545–608; Bather, F. A. Wind-worn Pebbles in the British Islands. Geol. Ass'n Proc. June, 1900. 16:396–420, with bibliography; Meunier, S. La géologie expérimentale. Paris. 1899. ch. 6. p.208–16.

tion uninterrupted by dust and sand falls not only because of the anchoring of the sands by ice over the dry land but also by reason of the ice covering of the lakes or estuaries in which the clays were deposited.

In this view, the sand partings of clays in this region should be thickest on the western side of the clay area and should wedge out to thin layers on the east, due allowance being made for the drifting, by currents, of the dust which falls into the water.

The interpolation of sand partings by recurrent wind action in something like cycles of one week agrees more closely with the probable rate of deposition of the observed strata than the supposition that the alternations depend on seasonal or diurnal changes; and instead of allowing 5000 years for the deposition of the clays in the Connecticut valley, for instance not more than one 50th part of that time would probably suffice under the conditions of excessive discharge of rock-flour from the neighboring melting ice sheet.

The sandy partings in clay often simulate the loess in character and it is in them also that the equivalents of the "loess pupchen" or "clay dogs" are frequently found. There is good evidence that many areas of loess are of eolian origin; but the sandy partings in subaqueous clay areas differ from loess in that the sand has come to rest beneath a water body rather than on an open air surface.

Succession of glacial clays. It has already been pointed out in the chapter on the effects of retreating glaciers how deposits on the same stratigraphic plane may be of different ages or stages of glacial retreat. Each proglacial delta has its supplement in clays extending from beneath it over the low ground in front of it. Thus the fact that in the lower Hudson valley we find clays underlying gravels and sands does not show that there was first a time of clay deposition followed by one of coarser deposits unless it can also be shown that the gravels and sands were simultaneously deposited by normal streams. The ice contacts in that region point clearly to a succession from north to south as the ice front receded.

Exceptional reasons for predominance of clay deposits in the glacial series of the Hudson valley. The dominance of clays in the Hudson valley from the Highlands to the mountains which

shut the lowland off on the north about the margin of the Fort Edward plain is in great part dependent on the preglacial history of the district. Throughout this area the graptolitic rocks forming the argillaceous facies of the Lower Siluric known as the Hudson river group and comprising the Lorraine and other bodies of fossiliferous shale form the walls and floor of the Hudson river valley and its gorge. All of the glacial erosion on this terrane could not but produce clay at every step in the trituration of the material. The shales even where more or less mountain built and cleaved give way in small bits rather than those large fragments which the ice sheet was enabled to drag out from jointed sections of the harder rocks in the districts on the east and west. To this original clay of the valley there was added the rock-flour brought in from the higher grounds of the valley sides whenever and wherever the drainage was free to concentrate in the main channel. Moreover during the draining of Lake Vermont (glacial Lake Champlain) much clay was moved southward and left in the upper Hudson valley.

Organisms of the clays in the Hudson river valley. A long and fairly diligent search has been made for fossils in the Albany clays and the earlier deposits which occur farther south in the Hudson river valley but without the finding of fossils which indicate the presence of the sea during the stages of clay deposition.

Ries has discovered the spicules of a sponge (Hyalonema) and fresh-water diatoms *Navicula gruendeleri* As., *Navicula permagna* Edw., *Melosira granulata* (Ehr.) Ralfs., *Nitzschia granulata* (Gruend). He also reports finding impressions in the blue clay at Croton Landing which the late Professor Hall regarded as worm tracks.

I have collected small sinuous trails from the clays at South Bethlehem agreeing closely with those mentioned by Emerson[1] from the clays of the Connecticut valley and referred to the larva of a dipterous insect (*Chironomos motilator*).

J. Eights in 1852 described fossil leaves from the clays near Albany. Emerson[2] mentions leaves known as *Mitchella repens*

[1] Emerson, B. K. Geology of Old Hamden and Hampshire Counties, Mass. U. S. Geol. Sur. Monogr. 43, p.720.

[2] *l. c.* p.718.

from the Hudson river clays and refers then to *Vaccinium oxycoccus* abundant in the Connecticut clays.

Other observers have from time to time reported fragments of wood and lignite in clays in or about the river gorge but much of this material appears to be of more recent origin than the strictly glacial and Albany clays (see paper by Fitch in bibliography at end of this report).

Indian shell heaps occur along the banks of the Hudson at various places, composed largely of the shells of oysters and these have occasionally been seen in situations which led to the belief that they were in place in the sands overlying or interstratified with the clays. An examination of such a supposed case on the Croton delta showed Professor Grabau and myself that the shells were in a talus and derived from an old shell heap at the top of the bluff.

As for the remains of a reindeer found at Sing Sing (Ossining), I do not know the circumstances under which it was found; but its occurrence is consonant with the view of nonsubmergence of the lower Hudson valley.

So far as present evidence goes it appears safe to state that no strictly marine fossil has been found to be indigenous in the waters in which the clays were deposited from the mouth of the Hudson to the vicinity of Whitehall; and further that no estuarine species are known in the clays or sands. This does not mean that the clays were not deposited at sea level with a communication with salt water on the south or at the north but that they may have been laid down at or as far above sea level as their geologic environment may demand.

Landslips. The disastrous landslips characteristic of many clay areas, as for instance those of the St Lawrence valley described by the late George M. Dawson[1] and the recent catastrophe in Norway reported by Dr Hans Reusch,[2] are not likely to occur in the Hudson valley for the reason that over the great portion of the clay area these deposits lie on the dissected and glaciated rock terraces of the river. There is no great thick deposit of clay

[1] Abstract in Am. Geol. 23, p.103.

[2] Reusch, Hans. Norges Geologiske Undersögelse, no. 32, Aarbog for 1900, Kristiania. 1901; Nogle optegnelser frê Vaerdalen, p.1–32; Jordfaldet ved Morset i Stjordalen, p.32–44; The Landslip at Morset, p.226–28. Some notes regarding Vaerdal, p.218–26.

in the Hudson valley. Still there are narrow tracts bordering the river bank as at Newburg where inconsiderable slips might cause much damage or loss of life. The confinement of the river within its rock gorge is a further protection to the masses of clay which remain on the borders of the river.

Landslips in a glaciated district particularly where clays are covered with gravels and sand or glacial till often simulate the irregular topography peculiar to undisturbed glacial deposits. Even the structure of glacial deposits may in some cases simulate broad landslip movements for the reason that under the pressure of overriding ice the subjacent loosely textured deposits have been disturbed in much the same way as in normal landslips; but the association of glacial features such as the indications of the former front of the ice sheet and the distribution of the deposits usually make it possible to discriminate landslip topography from glacial topography.

Contorted clays. Contorted clays have long attracted the attention of observers in the Hudson and Champlain valleys. Ebenezer Emmons[1] noted contortions in the clays at Albany and as early as 1846 referred the phenomenon to the sliding of upper beds over lower ones in the movement of the clay bank toward its unsupported edge. This explanation appears to be satisfactory for many cases in the clays laid down after the final disappearance of the ice sheet from the district. It finds confirmation in the numerous instances of the sliding of masses of clays or landslips which have been observed at one point or another along the banks of the Hudson.[2] The contortions can only indicate the beginning of a restrained movement of this nature. But there are other ways in which contortions may have arisen in this field, viz, through the advance of the ice sheet on the clays laid down about margins of the ice, and through the lateral flow of clays from the growth of superposed deltas of sands and gravels about the margin of the clay tracts, a cause of contortion in clays noted by Russell[3] in the dessicated Lake Lahontan of the Great Basin.

Contortion through the forward push of the ice along its margin is to be suspected in the case of the contorted clays in the basal portion of the section on Croton point; but the contortions can

[1] Emmons, E. 1847. *See* bibliography, 53.
[2] Dwight, W. B. 1886. *See* bibliography 45.
[3] Russell, I. C. Lakes of North America. Boston 1895. p.50, fig.7.

not be taken as a criterion of the presence of the glacier unless independent evidence of the presence of the ice be found and even in this case the direction of the overthrusting movement shown by the clays should agree with the axis of movement of the ice margin. As this movement in the clays would be away from the ice contact terrace it should be possible to discriminate in favorable situations contortion through gravitative sliding from contortion by ice thrust. In the Croton point case, there is evidence of the presence of the ice in the morainal revetment of the remaining portion of the old ice contact terrace on the north and the contortions have

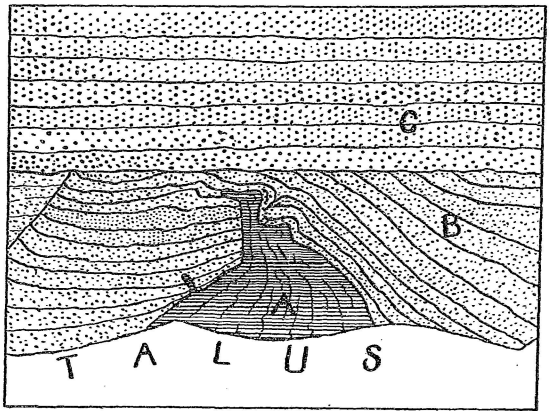


Fig. 23 Contortion and intrusion of clays in sand bank south of Port Kent railroad station, as seen July 31, 1900: A, the clay; B, the foreset sands of the delta; C, upper most undisturbed sand layers

their axial planes thrown over to the south away from the ice, hence it is possible to infer that a slight ice thrust is indicated here.

The case is described elsewhere in this report in which the ice sheet has overrun clays in the Hudson gorge between Schuylerville and Fort Edward, producing contortions of large size.

At many points where streams have constructed deltas on the margins of the clay area crumpling is to be suspected as an effect of the weight of the overlying sand and gravel. A rather marked case, probably a locality earlier observed by Ebenezer Emmons, is that of the southernmost lobe of the marine delta of the Ausable exposed in a section south of the railroad station at Port Kent on Lake Champlain. The sands which have here been deposited over the clays have resulted in the disruption of the latter in the manner of irregular dikes penetrating the overlying sands.

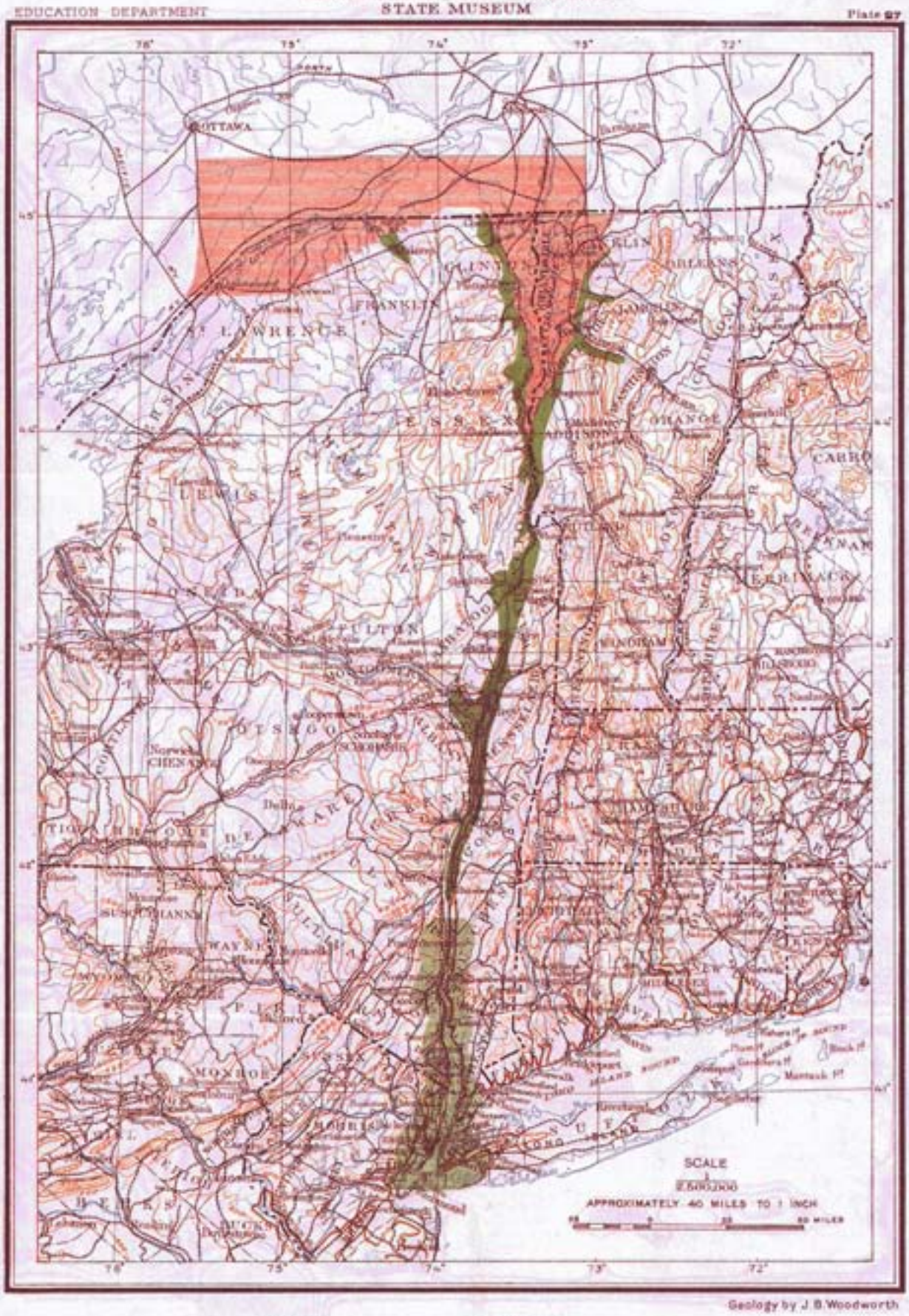
Chapter 9

LARGER GLACIAL LAKES OF THE CHAMPLAIN AND HUDSON VALLEYS (continued)

LAKE VERMONT OR GLACIAL LAKE CHAMPLAIN

From the failure of the higher shore lines of the Lake Champlain district to pass around the northern spur of the Adirondacks at Covey hill and thus westward along the northern flank of the mountains it seems as before stated necessary to postulate an ice dam across the mouth of the Champlain valley acting as a barrier to retain the waters in it up to these higher levels. The waters thus confined in the Champlain valley already recognized by Baldwin, Upham and others, have been referred to as glacial Lake Champlain. As this body of water was of far greater extent than Lake Champlain and came into existence independently of this smaller lake and moreover was separated in time from Lake Champlain by a marine episode in the valley, it seems best to employ a distinctive name. As the glacial lake covered practically much of the state of Vermont west of the Green mountains and probably penetrated through that range at its highest stages to the basins on the east of the mountains, "Lake Vermont" is used here instead of the descriptive phrase heretofore employed.

This body of water was apparently at first as noted by Upham confluent on the south with what is in this paper denominated Lake Albany. Just how far north in the Champlain valley the ice had retreated at this early stage depends on the interpretation of the higher gravel ridges and beachlike deposits in the northern half of the Champlain valley. On the extent to which the ice had retreated depends in turn the extent at any time of the lake toward the north. The outlet of these ice-dammed waters at this early stage of confluence across the present divide of the Hudson and Champlain basins is a matter which concerns the interpretation of Lake Albany on the south and is considered in that connection. Lake Vermont may be said properly to have come into existence when in consequence of a local lowering of the waters south of Fort Edward a discharge began across a barrier into the Hudson valley on the south.



Geology by J. B. Woodworth

CHAMPLAIN

Marine Deposits

LATE WISCONSIN

Deposits of Lakes Albany and Vermont and deltas about Malone.

Retreatal glacial deposits of Southern Hudson Valley.

Map of Lakes Albany and Vermont, and the Champlain marine deposits

Before passing to the notice of the outlet of Lake Vermont, it is desirable to determine, if possible, from the facts in hand the nature of the change which brought about a separation of the clay-depositing waters which extended from the upper Hudson valley into that of Champlain. On plate 28 of this report, a line (A–B) is drawn on the profile for the purpose of comparing certain water levels which occur at indicated points on the sides of the Hudson and Champlain valleys. The plane in which this line lies has a tilt from north to south at the rate of about 2 feet to the mile. The line is drawn through two of the highest beaches found between Port Kent and Sawyers hill at Street Road on the New York side of Lake Champlain. It is possible that these beaches are not contemporaneous. From Street Road to New York city there are practically no kettle holes now remaining unfilled in the drift below the levels which this inclined plane traces on the sides of the valley, except it be that the large kettle holes in and about Glen lake descend below the plane, with their tops, however, well above it. The kettle holes quite uniformly fall off in level to the south in rude parallelism with this plane of comparison.

From the southern border of the Highlands of the Hudson southward the sand plains and terraces contemporaneous with the retreating ice front rise to the northward in succession in close parallelism with this plain and approximately to equivalent elevations. Throughout the middle Hudson valley there is less accord in elevation of the actual deltas and this projected plane of comparison. It has proved well nigh impossible to find any systematic relation of the various water levels which are indicated in this portion of the valley, after making due allowance for such deposits as appear from their form or structure to have been built in waters confined along the ice margin or held up on the rock terraces of the Hudson gorge by ice remaining in it. In general there is clearly indicated, however, a rise of the water levels toward the north at something like the same rate of tilting as that indicated by the line of comparison; but the upper limit of the deposits falls below that of the plane of comparison as if at this later stage of delta building along the ice border in the river either the land had risen or, if it were

already well above sea level, the outflowing stream in the gorge on the south had more deeply excavated its channel so as to permit the draining of the waters of Lake Albany and the region on the north to a lower level. A general southward tilting of the whole region would have accomplished the same result during the early lake stage.

In choosing between the above views, it has to be noted that after the barrier was instituted in the upper Hudson valley between the lake waters of the Champlain and Albany districts the water levels established in the former area according to my interpretation of them as shown in plate 28 are tilted now much more steeply than those of the Albany clay region in the middle and southern Hudson valley. On account of the apparent close approximation of the water levels in the lower and middle Hudson valley to the line of comparison above mentioned it seems probable, though not to my mind thoroughly demonstrated by the analysis I have been able to make of the mass of details presented by the district, that the land remained fairly stable during the retreat of the ice sheet from New York narrows northward, such changes of level as are indicated by the altitude of the proglacial deltas and terraces being due to fluctuations in the water levels and the excavation of the drift in the Hudson gorge during the time that Lake Iroquois discharged through the Mohawk valley into Lake Albany. The land was then relatively to its present attitude tilted down on the north so that the line of comparison in plate 28 was essentially parallel to sea level. Following this essentially stable phase an actual down tilting to the north ensued with an axis of no change of level somewhere not far north from Albany, bringing the Champlain district into parallelism with the later shore lines including the marine limit as indicated in plate 28, and producing a corresponding uplift in the lower Hudson valley. This change of itself would have produced a rise of the waters in the glacial lake on the north of Albany in an increasing ratio with the northing and an apparent lowering of the shore lines in the valley south of Albany. This probably was the time of maximum water hight over the divide south of Fort Edward. The excavation or reexcavation of the Hudson gorge in the far south, favored by the increased current

due to the influx of waters from Lake Iroquois, gradually lowered the level of the waters in the lakes on the north till Lake Albany as such was drained, leaving Lake Vermont behind barriers of at first superficial deposits in the Schuylerville district and when these had been breached by the excurrent stream it was still held in by the divide in the floor of the Wood creek channel near Fort Edward. This hypothesis which regards the whole of the eastern part of the state as moving blocklike without essential warping in the tilting appears to me to have more support than the idea of warped levels. It regards the land as tilting down on the north as the ice went off, remaining down for a time, and then beginning the reversed upward movement which probably is still in progress over the north as its opposite is taking place at the mouth of the Hudson.

Outlets of Lake Vermont. The question of the outlets of Lake Vermont, the glacial lake held in over the site of the present lake Champlain and extending southward into the Fort Edward district, to which reference has been so frequently made in these pages, has not been completely exploited as yet by field work. The principal points remaining undetermined concern the possibility of an early high level stage of overflow through the Winooski valley into the Connecticut and a leaking out of the waters along the northern end of the Green mountains past the ice sheet into the St Lawrence gulf at a late stage in the lake history just before the marine invasion. Between the very high and the very low stages of level at which these contingencies might arise in the situation of the outlet of waters over the Champlain area there are a number of data which point to the location of outlets accordant with the intermediate lake levels on the hypothesis of tilting to the south. These outlets lie between the vicinity of Fort Edward and Stillwater in the upper Hudson valley coincident with and south of the present divide between the Champlain and Hudson basins.

The outlets in this vicinity are described below under the title of the Quaker Springs, the Coveville (or Dovegat), and the Fort Edward outlets.

Quaker Springs outlet. The surface of the western terrace of the Hudson gorge in the vicinity of the battlefield of Saratoga from near Quaker Springs southward to Stillwater is partially

stripped of its coating of clay and sand indicating as pointed out in the first part of this report that a powerful stream of water coursed over this path previous to the reexcavation of the Hudson gorge. This stripped floor has an elevation of about 280 feet above the sea near Quaker Springs. The stripped character of the ground is not perhaps at first easily perceived for the reason that the Hudson river slates and shales break down into clays very readily. On many of the farms in this belt the disintegrated and partly decomposed shales are directly invaded by the plow.

When water flowed over this bench the delta of the Batten kill must have extended in something like its original contour over the gorge of the Hudson and the Coveville channel near Schuylerville. The Albany clays must also have filled the Hudson gorge on the south. The occurrence of this spillway marks a new episode in the upper Hudson valley, the draining away of Lake Albany, and the beginning of the reexcavation of the Hudson gorge so far south as that had been filled by the clays of this lake. It remains to determine if possible the condition of the geography on the north of this spillway.

It should be stated that the writer was led to consider the Quaker Springs scourway as associated with the outlets of a glacial lake on the north on observing that a plane passed through certain higher water levels in the Adirondack region [*see* the line T–U, on pl.28] came to the level of the Hudson terrace precisely where this phenomenon of stripping was most marked. There must have been for a considerable length of time a very strong discharge of water along the ice margin and the western wall of the Adirondacks southward into the Hudson valley, following the ice edge throughout this distance so far as the ice still remained in the depressions or discharging into lakes of varying level at the ice front. The line above referred to has been drawn nearly parallel with that taken to indicate the marine limit at a later time. It will be noted that the plane nearly coincides with the top of the glacial terrace at Street Road as well with the later shore line imposed on the slopes of that marginal delta. Though what I have taken to be traces of the shores of water bodies occur along this plane of tilting northward to the international boundary in the embayments of the Cham-

the Champlain valley and that it had withdrawn as far north as Street Road but probably had not withdrawn as far north as Trembleau mountain at Port Kent.

Coveville outlet [*see* pl.11]. One of the singularities of the gorges lateral to that of the Hudson in the upper valley of the river is the arrangement of the Hoosic opposite that of Round lake, and farther north the opposition of the channel of the Batten kill to that of Fish creek the present outlet of Saratoga lake. The only feature however of these side gorges to which sufficient attention has been paid in this survey to warrant discussion is the old channel of the Hudson west of Schuylerville. Between Northumberland and Bacon Hill a trough about 1 mile wide at top and ½ mile wide over the floor overhangs the present gorge of the Hudson and extends southward to Grangerville where Fish creek valley enters it from the west. From this point the old trough extends southeastward to the west bank of the Hudson below Schuylerville, there overhanging the floor of the gorge at Coveville (the Dovegat of the Revolution), a remarkable recess in the western wall of the gorge. At Northumberland the restored contour of the floor of this old hung-up channel would make its present elevation about 220 feet above the sea; at Coveville the floor of this hanging valley is about 200 feet above tide. The cove at Coveville in its relation to this hanging valley shows clearly that a large stream at one time flowed southward over the wall of the gorge at this place into the main gorge of the Hudson river, and was arrested after a slight amount of cutting had been accomplished.

Fish creek now enters this old valley at Grangerville, flows along its eastern side for about 2 miles, turns sharply northeastward through a narrow and steep valley to the Hudson on the southern limits of old Schuylerville, falling approximately 100 feet in a distance of 2 miles.

The Hudson river must have at one time flowed through this Coveville valley at a time when the bed of the river was in this latitude approximately 100 feet higher than it now is. The 220 foot elevation of the old valley back of Northumberland coincides closely with the terrace on the east side of the river above Thompson and thence northward to the Moses kill. Furthermore the delta of the Batten kill northwest of Bald Mountain

settlement displays an eroded edge. Similar indications of the old level of the river exist on the west bank of the present gorge opposite Fort Miller. This drainage must have been active since the building of the delta of the Batten kill and before the reexcavation of the straight gorge from Fort Miller to Coveville, an inference which carries with it the corrollary that the old gorge was filled with drift at least from Coveville to somewhere near the mouth of the Moses kill. The occupation of this old side valley must have been relatively late, after the disappearance of lakes in the upper Hudson valley south of Fort Edward and likewise after the gorge below Coveville had been cleared of the sands and clays which must earlier have partly or wholly filled it.

The evidence of an old shelving water fall at Coveville shows that during the time a discharge was taking place through the outlet, the bottom of the Hudson gorge was there above sea level. What appears to be the old pool is now about 100 feet above sea level.

On the diagram, plate 28, the line C–D is introduced to show the beaches and deltas which it is believed are correlated with this outlet. It marks perhaps the most extended state of Lake Vermont exception being made of the addition which was later to come from the further retreat of the ice from the country north of Cobblestone hill near West Chazy.

Before turning to the lowest outlet, the following account of the phenomena in the lower valley of the Moses kill serves to show an intermediate stage in the excavation of the old drift filling of the Hudson gorge as well as in the outlets of the lake on the north.

Washed rocks near the mouth of the Moses kill. About a mile above the confluence of the Moses kill with the Hudson river the gorge widens out into a lower valley into which several streams come down from the terraces of the Hudson on the south and west with a backhanded drainage. The Moses kill entering this way on the east, turns sharply, once it is in this valley, to the southwest and hesitatingly enters the Hudson flowing first through a narrow vale between the main wall of the terrace and an outlying spur of rock on the floor of the valley. This spur composed of the Hudson river slates and characterized locally by a

needle slate structure, is almost completely bare of drift or clay. The entire knoll to the hight of nearly 60 feet shows signs of water action and strong scourways exist between minor knobs at its western base. The course of the current which did this work was evidently through the open valley in which Durkeetown lies and which joins the Wood creek valley near Dunham basin. The divide in this valley east of Fort Edward is about 170 feet; and the divide in the Fort Edward channel occupied by the canal is now lower having an elevation of about 150 feet. Both channels have been swept by strong currents, but as already indicated there are evidences in this field that the eroded clays in the low grounds about these channels as well as in the gorge of the Hudson are an early glacier-disturbed series.

Fort Edward outlet. The next lower stage of the glacial lake must have been determined by the hight of the divide in the bed of the Wood creek channel near Fort Edward. This broad almost level channel bears every mark of having been scoured by waters flowing through it. On the diagram, plate 28, I have correlated the deltas and beaches along the line E–F with this outlet. This was the lowest point of discharge on the south for glacial confined waters in the Champlain district. As shown later the marine limit appears to have fallen short of this col. In what manner the waters of the glacial lake fell to the level of the marine limit appears to be indicated by the crowded beaches along the international boundary where successive stages of lower and lower water levels are shown from about 540 feet downward. It is in this view almost necessary to suppose that the waters leaked out under or past the ice sheet along the northern border of Vermont. An examination of the country between Richford Vt., and Frelighsburg, Quebec, in 1904 failed to discover spillways. This is a question which has yet to be more fully investigated.

Reexcavation of the Hudson gorge. The history of the changes in the outlet of Lake Vermont in the region about Fort Edward and Schuylerville finds its parallel in the Hudson gorge farther south. Not before detailed mapping is done will it be possible to correlate all the lower terraces which record the changes which took place as the river sank toward its present bed. Some of these changes it can be shown took place very early in the southern part of the Hudson gorge and others very late in the history of

the removal of the glacial filling of the gorge. Of what appears to be an example of the first class the Moodna case is cited below. Other instances as that of the Kenwood terrace and the effects of the dissection of the delta of the Hoosic are certainly due to post-Albany changes of water level.

Terraces of the Moodna kill. The Moodna kill entering the Hudson gorge between Newburg and Cornwall [*see* pl.4] exhibits several minor terraces developed in the dissection of the heavy glacial terrace which stretches along the river bank at Cornwall. On the south side of the stream near the Hudson there is a clear record of a strong current of the Moodna depositing coarse gravel on the floor of the stream at the level of about 100 feet above the present surface of the sea. A deposit of this character so near the Hudson gorge and in soft material admitting of no fall indicates a local water level in the gorge about 100 feet higher than now. The same levels obtaining in the region about New Hamburg at the time the ice front was in that vicinity makes it very probable that this stage of terracing in the Moodna kill occurred as early as the Newburg stage and has nothing to do with the later stages of river work. There is a lower terrace in the Moodna kill at about 50 feet also well developed.

Kenwood terrace. What is here called the Kenwood terrace is a narrow somewhat shelving remnant of a terrace left by the Hudson in sinking its bed through the clays of its gorge just below Albany. On the right bank of the river from the city of Albany southward to and beyond Glenmont the edge of the Mohawk delta comes to the margin of the gorge with its summit line between 180 and 200 feet, rarely rising to 220 feet. The failure to reach the 200 foot level is noticeable where post-glacial erosion has taken place. The localities in which the line rises above 200 feet are conspicuous where underlying older deposits pierce the delta clays.

From McCarty avenue to Kenwood this upper terrace is confronted by a lower one with a deeply notched frontal slope. The northernmost spur thus formed is outlined by the 140 foot contour line and two southern ones by the 120 foot line. At Kenwood, denudation has uncovered the bed rock at about this level. South of Kenwood the 120 foot bench is quite distinct, gradually falling to about 100 feet just north of Glenmont. On the south of

Glenmont the 100 foot contour line embraces the continuation of this old terrace till it blends with the flats in the vicinity of Wemple. The terrace thus marked out near the 120 foot level is probably a congeries of terraces. It is noticeable that the system falls about 40 feet in a distance of 4 miles from north to south.

Dissection of the Hoosic delta [*see* pls. 10 and 24]. The delta of the Hoosic river constructed on the borders of Lake Albany at a level now as high as 350 feet above existing sea level has been dissected by the stream in its adjustment to the local Hudson drainage base. In this dissection, the Hoosic river has meandered in a most complicated fashion in the clays and sands of the delta terrace, leaving a rather confusing tangle of terraces within the gorge. The adjoining plate 24 shows the position of the more prominent of these terraces, which are grouped on the hypothesis that the uppermost are the oldest and the lowest the most recent, that those at approximately the same level are approximately of the same age. It will be observed that the highest terrace developed at 300 feet is traceable in the middle of the gorge; that below this is a series of fragmentary terraces from 280 feet near the rock falls to 260, 240, 220, and possibly indicated by one of the 200 foot benches near or at the mouth of the gorge. This last group was probably not made at one movement of the stream but represents several ancient grades in the sinking of the stream from 300 feet to 200 feet in the soft clays and sands below the rock at the falls.

The 200 foot terrace level is widely developed in the middle and lower part of the gorge and seems to indicate waters running at about this level in the Hudson gorge for a considerable length of time. Then follows a brief stage at 150 feet; followed by well incised meanders at 120 feet, and a brief stage at 100 feet. From this 100 foot level there appears to have been a drop rather quickly accomplished to the present channel which enters the Hudson at about 80 feet above sea level.

Scant as are the evidences here adduced there are other similar facts yet to be studied in this field, pointing to the filling of the gorge of the upper Hudson with drift deposits and with the overlying Albany clays, and to their subsequent removal on the withdrawal of the waters of Lake Albany and the entrenchment of the new Hudson river in the old gorge.

Chapter 10

THE MARINE INVASION

It has long been well known that as the Wisconsin ice sheet disappeared from the margin of its gathering grounds in Ungava, the sea at once covered large tracts about the shores of Hudson Bay, throughout the St Lawrence valley, along the coast of New Brunswick, Maine and New Hampshire, and probably also a narrow strip of the coast of Massachusetts north of Boston. The main geologic problem awaiting solution in these fields is that of determining the upper marine limit. The literature of the field presents the greatest variety of opinion on this subject, the vertical and horizontal range of the marine waters being limited by each writer according to very different criteria. While the earlier writers as a rule were inclined to regard the submergence as of great depth and wide extent, recent investigators exercising a closer and more cautious discrimination between the effects of glacial waters, lake waters and those of the sea have tended to restrict the submergence to narrower limits. As will be observed I have come to an essential agreement with Baldwin[1] whose paper on the Champlain district has the merit of including a diagnosis of the marine limit on the Vermont side of the valley.

THE UPPER MARINE LIMIT

The criteria appealed to by different geologic writers in the establishment of the upper marine limit in this part of North America indicates a wide diversity of opinion as to the effects of marine action and consequently as to the extent of the postglacial submergence in this district. All are agreed that the upper limit of marine fossils is a trustworthy though probably a minimum measure of the vertical extent of the submergence. Most geologists would probably also accede to the zoologic postulate that the marine limit does not lie higher above the shell line than the depth of water indicated by the fossils as necessary for their growth. Such is the present vertical range of most of the species found in the Champlain valley—100 to 300 feet—that they do not furnish a criterion for discriminating between marine beaches and glacial

[1] Baldwin, S. P. 1894. *See* bibliography, 1.

lake beaches which latter there is reason to believe on other evidence lie within 300 feet of the upper limit of marine fossil shells.

When the beaches and bars of Lake Iroquois, a preglacial lake, are compared with the beaches of the marine district in the Champlain valley, the evidence is overwhelming that the lake beaches are much more strongly developed than those which may be ascribed to marine action in the latter field, the reason for this being that the lacustrine action continued at a given level for a greater length of time than did the marine waves. There is in short nothing in the local character of a lake beach to distinguish it from a marine beach. The geographic situation and the horizontal distribution of the beach phenomena on the other hand may furnish differentiae. Proglacial lake beaches run out against the glacier against whose front the waters are held up; in the opposite direction the beaches converge to one or more spillways whence the overflow discharged to the sea. Marine beaches and correlated shore phenomena develop about the entire periphery of an area of submergence, and phenomena of outflow are necessarily absent.

This criterion of continuity of beaches has been used in the present survey to distinguish the upper marine limit from earlier higher lacustrine shore lines which, as the evidence indicates, end abruptly as they are traced toward the Covey hill spur of the Adirondacks. In the district where these higher beaches, for which a proglacial lake origin is claimed, disappear, some phenomena demand further discussion in relation to the validity of the assumption made in this paper.

The water planes marked by deltas and beachlike deposits above 450 feet on the Mooers quadrangle, come at the international boundary to their northern limit indicating that the ice front impinged on the Covey hill spur and separated the waters on the east of the Adirondacks from those on the northwest. If it be supposed, however, that just previous to this stand of the ice the glacier had retreated, as it did later in the final liquefaction, far enough north to open free communication between the Champlain valley and the upper and lower St Lawrence (as Mr Upham has indeed supposed to have been for a time the case), then a beach or beaches would have been continuous about the spur only to be smoothed off and rearranged by the advance of the ice to the position to which the

beaches may now be traced. Such an oscillation of the ice margin as is here merely suggested, undoubtedly took place, and the possibility of it constitutes the weak point in the argument presented in this report in the attempt to fix the upper marine limit.

Such diffused shore lines might be expected to exhibit a trace in the waterworn character of the glacial drift along the belt in which the overridden shore lines were formed, in the case of a temporary and slight advance of the ice, one which, in this field need only have amounted to an oscillation of from 10 to 15 miles.

In this connection, it should be stated that certain peculiarities of the drift before referred to along the western border of the Mooers quadrangle from Deer Pond northward to the English river at Cannon Corners are not inconsistent with an advance of the ice such as is here considered possible. Waterworn drift varying from gravel to very coarse cobblestones with on the whole an unstratified structure and ice-swept contour covers the slope between the 700 and 800 foot lines quite above, however, the latest lake levels of this latitude.

These deposits lie, it should be noted, on the east of Blackman's rock, one of the large spillways of bare Potsdam sandstone, only the northern extremity of which appears on the map. It has seemed to me that the waterworn materials are to be ascribed to stream action contemporaneous with the position of the ice front along this line rather than to the involution in the drift of an earlier beach deposit formed at a higher stand of the sea than is advocated in this report. The fact that there are no clear traces of such smudged beaches around the Covey Hill slope has confirmed me in the belief that this objection to the accepted marine limit has in this case no clearly observed facts upon which to rest.

A second objection to the view that the higher beaches in the Champlain district are of lacustrine origin may be raised from the fact that along the slope of the Adirondacks the lowest shell-bearing layers of the marine series, as at Mooers on the Big Chazy, and Freydenburg's Mills on the Saranac, are found resting directly on the boulder clay without intervening nonfossiliferous beds or those bearing nonmarine fossils attributable to the deposits of a lake. The absence of lacustrine deposits in these two localities in the northern part of the area can

hardly be explained away by the supposition that during the lake stages the region where they occur was covered by the glacier so as to prevent deposition and that the ice retreated in such a way as, at once, to admit the marine fauna to the area, for when the ice front was as far south in the Champlain valley as the Saranac, it still had a long retreat to make before a passage would have been open through the Missisquoi region for the entrance of the sea with the Labradoran fauna. Before this could happen some nonmarine sediment most likely would have been deposited particularly near the mouths of streams, off which both of the localities here cited then lay. It seems more likely that this belt between 300 feet and 350 feet was so far from the lake shores as not to receive contributions of sand and gravel there being no tide to augment the offshore scouring, and that the clays were carried by the circulation of the waters to other parts of the lake floor.

Cut cliff in till near Port Kent. At only one point on the New York shore of Lake Champlain have I recognized what appears to be an old sea cliff entirely cut by waves. This cliff has been cut in a thick mass of till on the northwest flank of Trembleau mountain midway between Port Kent and Keeseville. The cliff may be seen at the old tollgate, now abandoned, on the direct road between the places named. The base of this cliff is practically at the level of one of the elevated stages of the delta of the Ausable river. According to the local contour of the United States Geological Survey atlas sheet the base of the cliff is about 330 feet above the present sea level.

The cliff is somewhat less than 100 feet high and extends for fully a third of a mile. It is a conspicuous object in the landscape from any point of view on the north and east because of the contrast of its somewhat ravined face with the smoothened or horizontally lined slopes which form its topographic setting.

I hold this to be a wave-cut rather than a stream-cut bank or cliff for the reason that the slopes of this mass of till, high above the cliff, exhibit numerous water levels showing that the ice sheet had retreated from this vicinity long before the cliff cutting began. It is to be presumed that this cliff was the work of waves during the marine invasion. Certainly those which acted on the higher parts of this till mass, either had no

such power as did the waves at the 330 foot level or if they had this strength they acted for a much shorter time at each level. It is to be presumed, when the mouths of the Champlain and the St Lawrence valleys were freed from the ice sheet, that the winds from the north and east would have had a greater fetch and that the glacial lake conditions of the higher water levels would be at once exchanged for more vigorous cliff cutting. It has therefore seemed to me highly probable that this cliff has its base approximately at the marine limit. There is another consideration which supports this view.

It is to be shown presently that the marine limit of this epoch is now tilted more steeply to the south than the shore lines of the earlier water-levels on the south. It appears to follow from the divergence of these ancient water planes, that before the marine invasion was established, the land was tilted down toward the north, thus determining the extent of the submergence; since then the land has risen. The marine action would undoubtedly be longer maintained at the level of the maximum of depression of the shore lines, for there the sinking land halted, reversed its movement and came up. Thus we ought to find, other opportunities being equal, rather decided evidences of wave action at this particular water level, for the land probably stood longer at the marine limit than at any other stage in its movement.

On the basal slopes of Trembleau mountain to the east of the cliff, are patches of beaches with well waterworn pebbles between the bare ledges at about the level of the base of the cliff above described.

There is also a very extensive development of the gravelly and sandy delta of the Ausable just below this level indicative of a longer stage of delta building than is found again below this level. If I am not mistaken Mr S. P. Baldwin has taken this delta to mean the same thing—the local index of the marine limit.

True proportions of the postglacial tilting of the upper marine limit. Lest the reader obtain from the diagrammatic profile of plate 28 an exaggerated idea of the steepness of the tilting of the old sea level in the Champlain valley, let him construct a straight line 1 mm thick having a length of 1196 mm. The thickness of this line will have the same proportion to the hight of

the uplifted seashore as the length of the line has to the extent of the old shore line above the present sea level within the limits of the State in a northsouth direction. Imagine a diagonal line passing from the top of the thickened black line on the right hand end to the bottom of the line on the left hand end. Then the inclination of this oblique line will slope at the same angle or rate a mile as does the upper marine limit of the Champlain submergence. The rate of rise of the upper marine limit is on this basis 4.411 feet to the mile to the north.

MARINE DEPOSITS OF THE CHAMPLAIN VALLEY

Lithologically the marine deposits of the Champlain valley are commonly referred to as clays but while this facies of the deposits is most striking in the vicinity of the lake, the area exhibits the normal threefold development of sediments under the transgression of the sea: viz, along the shore line, beaches and bars of pebbles and shingle together with stream deltas of sand; farther off, sandy bottoms; still farther from the shore line, clays.

In the case of the Champlain valley, the normal character of the three belts or zones of marine deposition is largely modified by the composition of the glacial drift previously laid down in the region. Each of the zones above named may exhibit boulders and coarse rubbly material. Furthermore, in the retreat of the sea or rather the rise of the land, each belt in turn has been passed over by the shore of the sea and the processes peculiar to the littoral zone have more or less strewn coarse waste over the sea bottom of the preceding stages. In general, however, there is a cobblestone, shingle, or pebbly zone on the foothills bordering the lake, a sandy zone over the flats at variable distances from the lake shore, and a clay zone adjacent to the lake. The zones are of very variable width on the New York side of the lake, all of them becoming narrower toward the southern contracted end of the present lake.

Out of the sandy and the clay zone rather characteristically rise older deposits of glacial till or gravels, which for a time existed in turn first as shoals and then as wave-washed isles in the receding sea. These hills have generally lost their original outline as drumlins or morainal mounds with kettles. At top a beach or bar has been heaped by waves and gravels and sands have been washed down the sloping sides, the finest sediments being strewn over the

surrounding flat as a shallow water sea bottom deposit. The hill, at least one slope of it, is frequently left strewn with boulders from the washing out of the material which could be more readily removed by the waves and currents. The annexed diagram showing the cross-section of one of these shoals north of Mooers Junction illustrates a typical case.

It is a noteworthy fact that in a few cases in this area, heavy beaches of rolled pebbles occasion the western flanks of these northsouth glacial hills, while on the eastern slope large boulders lie out on a surface which exhibits otherwise no marine action other than probable erosion. This peculiarity is brought out in the diagrammatic section given below.

Subdivision of the marine beds. The marine beds frequently exhibit in limited sections a passage from clays below through

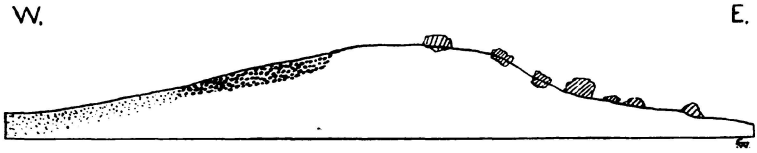


Fig. 24 Modified glacial hill with a beach. This hill has been successively a shoal and an islet

sands upward into gravels or even much coarser deposits. Particularly is this often the case in the sand zone. Nearer the present lake shore or on the inner borders of the clay zone sections reveal sands alone overlying clays. It is evident from the various sections and from the history of the changing sea level that the clays of the middle of the valley represent the deposits made there through the episode of marine invasion; that the lowest of these marine clays correspond in age to the highest marine beaches; that the highest of the clays correspond nearly to the lowest beaches now above the lake and clay levels. Pebble beds, gravels and sand, as well as clays must have been making during the entire epoch; it is therefore not feasible to establish time divisions on these lithologic characters. There is no such time division in the Champlain area as that of the Leda clay and the Saxicava sand but these biologic terms may be applied to facies of the deposits occurring in zones of more or less contemporaneous development.

DISTRIBUTION OF FOSSILS IN THE CHAMPLAIN DEPOSITS

The occurrence of marine fossils in the clays and sands of the New York Champlain beds has long been well known, but scant reference is made in the literature to their upper limits. In the course of the present survey search was made for fossils mainly within the zone of beaches above the zone of clays. In the following notes references are made also to the occurrence of fossil shells found on the northwest slope of the Adirondacks as far west as Ogdensburg. For the purpose of showing their bearing on the reconstruction of the upper marine limit in this region notice is also taken of certain shell-bearing localities in adjacent parts of Canada and Vermont.

As early as 1849 Prof. H. D. Rogers called attention to the fact that the then known shell localities in this geologic province indicated a want of parallelism between the water level of their epoch and that of the present seas. In recent years much more attention has been given to the evidence of warping of the earth's crust as shown by the deformation of traceable shore lines in the district of the great fresh-water lakes which came into existence with the withdrawal of the ice sheet. In a region like that of the upper St Lawrence and Champlain valleys, where beaches occur referable partly to lacustrine and partly to marine bodies of water, the evidence from fossil shells is of more than usual importance.

As having a slight bearing on the distribution of the marine fossils within the State, the occurrence of shells at Ogdensburg and Norwood is here recorded, but the discussion of the upper marine limit in that direction is withheld till a more complete examination of the district has been made.

Fossils at Ogdensburg. This locality has long been known. In 1903 Prof. A. P. Coleman collected Macoma groenlandica from the clays on the low ground in the southern limits of the city, and later in the same season both he and myself found abundant separated valves of the large Macoma calcarea with those of M. groenlandica and rarer Saxicava rugosa in stratified sands on the border of Ogdensburg and the town of Lisbon about ½ mile south of the St Lawrence at an elevation of about 281 feet above the sea. Professor Coleman

also found at this locality a single example of the gastropod Cylichna alba (?) apparently identical with the form now rarely found at Port Kent. The bivalve shells in this sand deposit invariably exhibited signs of transportation in that most of the detached valves were lying outside up in the sand layers after the manner of shells moved by rather gentle currents. Whether in their original matrix or not, the shells afford good evidence of the marine invasion to this point and to the altitude given.

Fossils at Norwood N. Y. Fossil shells of Macoma groenlandica are abundant in the clays at Norwood, St Lawrence co., N. Y., particularly in the low ground in the western part of the village. The sewer trenches opened in the summer of 1903 brought to light numerous pockets of these shells. I found this shell in clays under sands and lying on boulder clay about 3 feet below the surface near the street crossing the Rome, Watertown & Ogdensburg Railroad south of the Union station, at an elevation of about 335 feet. The same shell appears in the clays from the sewer trench on top of the hill in the northern part of the village at an elevation of 360 feet aneroid or 370 feet according to the engineer's levels compared with Norwood station. I also found Macoma groenlandica in a cutting of the Norwood & St Lawrence Railroad just northeast of the junction at Norwood at an elevation by aneroid of 350 feet. These shells were in stony clays, the rubbly marine drift, at the western base of the dune-capped hill which forms a prominent feature on the northeastern outskirts of Norwood. This region includes the highest shell locality yet discovered on the northwest slope of the Adirondacks and is, so far as I have been able to ascertain, the highest yet reported within the State. The locality is nearly 30 feet higher than the highest shell layer that I have seen in the Champlain valley but shells are to be expected in the western part of the town of Mooers as high as 400 feet.

Fossils at Montreal, Canada. The deposit of marine shells at the Côte des Neiges on Mt Royal is said to consist of a bed of gravel 6 feet thick with Saxicava rugosa and Macoma (Tellina) groenlandica. According to Sir Charles Lyell[1] the deposit is covered by an unstratified mass of boulders

[1]Lyell, Sir Charles. Travels in North America. N. Y. 1845. 2:119.

and gravel 12 feet thick. It is not altogether clear from the descriptions of this locality whether this overlying unstratified material is true till or a bed of coarse rubble washed down from the mountain side on the shell bed during the higher stand of the marine shore line at that place. It has apparently been assumed by Sir William Dawson and others that the shells pertain to the post-Wisconsin phase of depression. At the time of my visit in 1900 I was not, unaided, able to identify the locality. I have assumed in this paper, nevertheless, that the current view of the essential contemporaneity of the bed with other high level marine shells in the region is correct.

Fossils at Hemmingford, Quebec, Canada. Marine shells occur in Hemmingford, about 5 miles north of Mooers Junction, in a gravelly shoal on the southern margin of the village. A borrow pit in a pasture opened in 1903 afforded abundant shells of Saxicava rugosa in the attitude of growth in the openwork gravels at depths from 18 inches to 3 feet below the surface. The shells are large and strong and exhibit marked variations in form. From aneroid measurements, this locality appears to have an elevation of 257 feet. Saxicava also occurs in an old gravel pit on the west of the road at the same locality.

The freshness and strength of these shells at so slight a depth beneath the soil in gravels open to the free percolation of rain water is strong evidence against the supposition that the absence of marine shells in the sands and clays deposited about the margin of the retreating Wisconsin ice sheet along the sea border from New York eastward to the vicinity of Boston is to be explained by their removal in solution under the influence of meteoric waters following an uplift of that coast from beneath the sea.

Fossils near Mooers. The writer found marine shells on the south bank of the Great Chazy in 1903, at a point on the west side of the narrow neck of land in the sharp bend of the river ¾ mile above Thorn's corners.[1] The section there exposed shows about 10 feet of compact grayish sandy till resting on the Potsdam (?) sandstone. The surface of this till is planed off to a

[1] A picture of this locality is given by Cushing in the Annual Report of the State Geologist for 1895, pt 1, p.511, pl.III, Albany, 1896. The fossils occur at and above the dark line half way up the river bluff. Thorn (on the U. S. G. S. map) is given as Thom in the state reports.

level line of unconformable contact with overlying sands and clayey sands from 3 to 5 feet thick, in which near the base occur marine fossils. Overlying this bed are coarse waterworn gravels believed to be laid down by the river when its bed there was the top of the terrace now 340 feet above sea level. The following species were collected.

Macoma groenlandica....	rare	
Saxicava rugosa.....	dominant	
Leda arctica.....	not rare	
Yoldia (Portlandia) *sp*...	rare.....	J. W. Dawson. Canad. Ice Age. p. 241-2 Verrill. Invert. Anim. Vineyard Sound, p. 689
Balanus *sp.* fragments..	rare	

Saxicava rugosa, Leda, etc. are in the lower clayey bed usually intact and in the attitude of growth.

This locality is close to the 340 foot contour line of the United States Geological Survey map. Similar sands and clays are seen on the north side of the river below the bend at a point north of the camp meeting ground. The shell-bearing deposits are in strong contrast with the coarse wave and river strewn materials indicating the recession of the sea, and evidently pertain to the maximum marine stage following the disappearance of the ice from the locality. The smooth surface of the till on which the deposits rest and the apparent absence of beds referable to a lacustrine stage are rather characteristic of the marine series at this level from the Saranac northward. The same smoothness of the inclined surface of the till in the Saranac section at Freydenburg's Mills is noted below.

Fossils at Freydenburg's Mills on the Saranac. This locality, first noted, I believe, by Dr D. S. Kellogg and S. P. Baldwin, is one of the highest localities of marine shells on the New York side of the Champlain valley. The section as exposed in 1901 along the tracks of the Chateaugay Railroad reveals gravels and sands unconformably overlying the boulder clay. The till is a compact unstratified mass composed of bluish clay and clean, well striated boulders. No traces whatever were seen of the fossil shells in this lower glacial deposit. The surface of the till was

eroded and its trace in the vertical section was that of a smoothened plane dipping gently eastward toward the lake.

The shells occurred mainly at the base of the stratified deposit in sands resting directly on the till without trace of an intervening unfossiliferous bed such as might have been laid down on the till after the retreat of the ice sheet from the locality and the incoming of the sea. The upper part of the gravels appear to be of delta origin being on the whole coarser than the lower part of the water-laid deposit. The top of this deposit is over 340 feet according to aneroid measurements; and the fossil shells occur from near this level down the slope of the inclined bedding to perhaps 320 feet.

The following forms were collected, named in the order of their abundance: Saxicava rugosa, Macoma groenlandica, Balanus sp., Mytilus edulis.

Ries found Diatoms in the clay at Plattsburg. Shells and bones have also been reported at this lower level.

Fossils at Port Kent N. Y. One of the best known localities in New York for the occurrence of Champlain fossils is at Port Kent. Ebenezer Emmons[1] who gives two plates of fossil invertebrates found in the marine beds from various localities in northern New York, New England and Canada, states that he found the following list of species at Port Kent:

Tritonium anglicum	Tellina *sp.*
T. fornicatum	Tellina *sp.*
Mytilus edulis	Turritella
Pecten islandicus	Nucula portlandica
Mya truncata	Bulla
M. arenaria	

Sir Charles Lyell also gives an account of the shell locality at Port Kent. In a small brook south of the place (near the present railroad station) he observed at the bottom of the section: first, clay 30 feet thick with boulders; second, loam with shells 6 feet; third, sand, 20 feet thick. He found four species of shells: Mytilus edulis, Saxicava rugosa, Tellina groenlandica, and Balanus miser. He states that no shells were found at a greater hight than 40 feet above the lake (about 138 feet above sea level).

[1]Geol. N. Y. 2d Dist. 1842. p.128

at Burlington at about 202 feet; at Charlotte, at 150 feet; at Panton, 320 feet.

Mr S. P. Baldwin in 1894 reported other occurrences as follows: at Vergennes at nearly 250 feet; from central Addison northward at almost any point less than 150 feet; at Shelburne Falls at 180 feet; in the northern part of Shelburne shells are reported as high up as 400 feet (?); in the delta of the Lamoille, shells in the vicinity of a terrace rising to 450 feet.

The localities at which shells have actually been observed by competent witnesses in Vermont agree very closely with the range of the highest localities in New York. A tilted plane standing at an elevation of 450 feet at the northern boundary of the state and meeting the surface of Lake Champlain at Whitehall would lie above the localities at which there is good evidence of marine shells. The apparent exceptions are both noted in Mr Baldwin's paper. First and most important is the reported occurrence of fossil shells by the Vermont Survey of 1861 in Elgin spring at Panton, at an elevation of 320 feet in the latitude of Essex N. Y. Messrs Baldwin and Richardson on visiting the locality state that they were unable to find any trace of the shells. If, as I understand it, the original report was based on shells believed to have been seen in a spring, little reliance could be placed on shells actually so found for the reason that the shells may have been washed out from the underlying loose sand and clay of the Pleistocene series and carried upward to the mouth of the spring, a position in which it is common to find rock particles swept upward from a depth. I have, in view of these considerations, been led to reject the Panton locality.

The second case is that of shells reported to Mr Baldwin at an elevation as high as 400 feet in the northern part of Shelburne. This locality appears from the evidence in New York to be too far south for shells at so high an elevation and as Mr Baldwin did not see them I am inclined to think he may have been misled, as I was early in my search for shells in this field, by descriptions well meant but totally misleading which I also was able to obtain from some of the inhabitants. One very promising case of shells having according to my informant all the characters of a Macoma of some sort turned out on going with him

to the locality to be nothing more than conchoidal fracture chips from the checking of the clay as it dried in the sun. Small concretions have also been found to constitute the basis of an informant's description of fossil shells. If I understand Mr Baldwin's interpretation of the marine limit in the Champlain district he also considered the two localities above mentioned as negligible.

Ebenezer Emmons[1] states that two fossils shells, including Saxicava rugosa, are found the entire length of Lake Champlain, but he cites no locality south of the southermost named in this report nor have I been able to get a record of any such southern extension of the fauna.

Depth of the submergence indicated by fossils. The bottom of the sea within the reach of continental deposits is a surface sloping from the shore out into deep water, and is normally divided into a zone of pebbly and sandy deposits at the shore, a zone of sandy deposits farther out, and still farther out a zone of clay. The pebble and sand zone is the littoral belt; in tidal seas, bared at intervals to the atmosphere. The sand zone proper is in shallow water; the clay zone extends from the sand zone out into deep water. Each zone of bottom varying thus in its lithologic character differs also in its depth of water and consequently the pressure and temperature of the water and thus each zone becomes the abode of different animals. The marine shells found in the clays and sandy clays of the uplifted sea bottom in the St Lawrence and Champlain valleys are, according to Sir William Dawson, like if not identical with those of species now living in the lower St Lawrence river and gulf at depths less than 100 fathoms. The beaches of the sea in which the marine shells in the Champlain valley lived should not then occur more than 600 feet above the shells. Sir J. W. Dawson regarded the fauna at Beauport, Quebec, as living in from 100 to 300 feet of water. The species found there include most of those known in the Champlain valley. Evidences of water levels exist in the Champlain area between 600 and 700 feet above the present sea level. As shown in the diagram [pl. 28] the known localties of marine shells ranging as high from 540

[1]Geol. N. Y. 2d Dist. 1842. p.283–85.

to 560 feet on Mt Royal at Montreal, are found at successively lower levels in the Champlain valley, and the upper limit at which shells have so far actually been found passes below the level of Lake Champlain at Ticonderoga.

All the beaches whether marine or lacustrine in the Champlain district on the New York shore occur therefore within the range of possible marine surfaces as indicated by the fossils. The fossils alone do not therefore suffice to fix any one of the levels as the upper marine limit. Independent evidence must be advanced to show what and how many of the higher beaches were like those of Lake Iroquois, on the west of the Adirondacks, formed in an ice-dammed lake.

A comparison of the line, drawn through the highest known localities of marine shells at the eastern base of the Adirondacks, with the line showing the upper marine limit in that field shows that the fauna composed of Saxicava rugosa, Macoma groenlandica, Mytilus edulis, and a species of Balanus falls off in elevation toward the south at practically the same rate as the phenomena which are taken to indicate the highest stand of the ocean waters. As sea level, during the uplift of the land, stood in succession at all points below the upper marine limit, it is not always possible to determine the relation of the sea to the land when any particular deposit of shells was made; but if this upper range of shells in this district affords any ground for an assumption as to the upper marine limit in the inland waters on the north side of the Adirondacks it is to be presumed that there also the upper marine limit will be found closely coinciding with the highest shell deposits when these have been more fully ascertained.

NOMENCLATURE OF THE MARINE DEPOSITS

Each generation of men as it comes into possession of its inheritance of facts and theories in any department of science and gains knowledge of its own, finds something unsuitable in the names applicable to views and bodies of fact whose limits and relations have in their hands come to be notably changed. In the course of the collection and comparison of data centering about some early observed phenomenon the name of the type

thing becomes gradually extended in a generic sense to phenomena which in the later stage of critical classification appears to have been given too extended a meaning, if it has not in a premature broad generalization been made to embrace phenomena which in the later stage of critical classification appertain to a different system of distribution in time and space. Quite often, owing to the limits placed on the choice of terms, it is discovered that the name itself has been preoccupied by use for a very different object. In short the history of many scientific names is somewhat as follows.

In the so called natural history sciences names are first given with the purpose of defining exactly some object, be it fish, plant, land form or terrane. Being the type of its kind, similar objects having some essential likeness, structure, form, mode or time of occurrence are grouped with it under the same name. As nature in her prodigality never exactly reproduces her creations, some of the objects present differences of one sort, some of another, so that the name inevitably comes to have a broadened and weakened meaning in proportion to the number of occurrences which it is construed to designate. In time it thus loses its original definite meaning and being replaced here and there by terms of more accurate definition falls gradually into disuse. Its friends may endeavor to save it either in its original sense or with a restricted meaning in some respects different from its original use; but it has now lost its chief value as a scientific name since it is ever a source of confusion to the reader who has to carry in his mind, if he knows his subject, the fluctuating values of the word in the different periods of its history. In all this, scientific terms but exemplify those laws of use and disuse to which any words of the language are subject. The names which have been introduced for the fossiliferous marine deposits described in this report appear at present to be under the operation of these laws. The term "Albany Clays" specifically applied to the glacial rock-flours of the Hudson valley north and south of Albany in 1846 antedates the name Albany since given by Texan geologists to certain carboniferous beds in Texas.

In 1850, Desor[1] gave some account of the fossiliferous clays and sands of the St Lawrence valley and very appropriately called them Lawrentian. They constitute the only example of a geologic formation whose principal and most typical area lies within the basin of this majestic river. Only one other name is so suggestive of their distribution, that of Quebec in which province they chiefly lie.

In 1853, Logan unfortunately employed practically the same name in the term Laurentian in the official reports of the geological survey of Canada for a group of rocks believed to be at the base of the geologic column, and Desor's proposal failed of adoption despite the claim for priority which might have been made for it. In fact Desor's term appears to have been overlooked till the Vermont geologists came to decide on a name for the marine deposits of recent date within the area of that state, when it appears a second unfortunate choice attended the naming of these ill appreciated marine deposits.

In the *Report on the Geology of Vermont* by Edward and Charles Hitchcock and Hagar the term Champlain clays was adopted to designate the marine fossiliferous beds along the Vermont shore of Lake Champlain, the name being proposed in part for the reason as stated that Desor's prior term had been appropriated and was in established use for rocks of a very different age. In this connection the belief was held that the term *Champlain group* introduced into the New York reports by E. Emmons in 1841 had fallen into disuse, a condition in which the term has certainly been up to its proposed revival by Clarke and Schuchert in 1899.

In the employment of the term Champlain by the Vermont geologists in 1861 its meaning was made sufficiently clear as applying to the marine beds which there followed the glacial drift, though the formational term *clays* seems rather to parallel it with the biologic term Leda clay proposed by J. W. Dawson in 1857, neither term being strictly applicable to the entire series of deposits laid down under this marine invasion, a fact which was partially recognized in Canada by the use of the term Saxicava sand in the same year. The term Champlain having been

[1] Bost. Soc. Nat. Hist. Proc. 1850. 3:357–58.

thus newly defined, during the slumbers of the Silurian sense of the name, quickly passed in American geologic literature into an astonishing breadth of meaning and usage as wide as the continent itself and was stretched to embrace deposits laid down before, during and after the peculiar drift deposits from which in the Vermont report of 1861 the Champlain clays were accurately discriminated as the result of a definite process acting at a subsequent time. Whatever confusion may be attributed to the application of the term Champlain to the postglacial marine deposits of the northeastern part of America by the Vermont geologists it is clear that the original account did not contemplate the inclusion under this term of practically all the Postpliocene stratified sands and clays in other parts of the continent. This most extended use of the term is found most clearly set forth in the third edition of Dana's *Manual of Geology* of 1880.

The advances made in the past two decades in the separation of the glacial drift into distinct epochs of ice advance and the introduction of such a term as Wisconsin for the last series of ice sheet deposits has tended among other causes to leave the term Champlain as employed in Dana's *Manual* a synonym for an ill assorted and broken up collection of facts, there remaining only for its exclusive use the original marine beds of the Champlain and St Lawrence valleys and their equivalents elsewhere, for which the term was originally proposed by the Vermont geologists. In this restricted sense for which a name is and ever must be needed the name would be appropriate did it not find itself confronted with a contest for survival by the resurrected Champlain group of the lower Silurian whose title to recognition according to the law of priority which should govern all scientific names is clear but whose rehabilitation must nevertheless, in view of the circumstances above detailed prove a source of confusion. In fact to continue the use of either term from now on is to involve any context in which they are introduced in some obscurity. The happiest solution of the difficulty presented by the present status in geology of the name Champlain would appear to be to allow both applications with whatever postfixes to become obsolete in geologic literature. The name of Samuel de Champlain as much as we admire his high character

and valorous exploits is sufficiently memorialized in American geography by the beautiful lake which bears it, without his patronymic being seized on as the designative of geologic events of which he must have been ignorant.

The ancient name of Lake Champlain, Lake of the Iroquois,[1] has in recent years been applied to the great ice-dammed glacial lake which in the Ontario basin preceded the marine invasion. The name Quebec now obsolete and replaced by standard names is still retained by the Canadian geologists as a local designative; its use in Pleistocene geology would be ill advised on account of the history of the term as recorded in the literature of North American geology. The only safe course, it would therefore seem, is to propose the adoption of a name free from the entanglements of meaning and the confusion which surround the names Champlain, Quebec and Laurentian. The best studied section of these marine fossiliferous beds is that of Montreal, the ancient site of which city was occupied by the Indian settlement of Hochelaga. It is therefore proposed to call the deposits of this marine invasion the Hochelagan formation and the subepoch or stage of their time of deposition as the Hochelagan, a phase which follows the Wisconsin with its late lacustrine stages contemporaneous with the departing ice sheet.

HISTORY OF OPINION CONCERNING THE SOUTHERN EXTENSION OF THE MARINE CONDITIONS

Once the marine origin of the fossiliferous clays in the Champlain valley was recognized, the difficulty of separating these deposits from other similar materials naturally led to the conclusion that the marine waters passed through one or more of the narrow straits separating the Champlain from the Hudson valley and thence continued to the ocean on the south. The following writings and their dates are given only as an illustration of the history of ideas. The latter two by Upham and Baldwin anticipate the present report.

The views of the earlier Vermont geologists concerning the southward extension of the marine invasion is expressed in a

[1]The Indian name of Lake Champlain is stated to have been Caniaderi-Guarûnte. Kanyatare is Mohawk for lake. Doc. Hist. of State of N. Y. 1850. 3:1190.

geological textbook by Alonzo Gray and C. B. Adams.[1] The submergence indicated by the fossiliferous clays in the valley of Lake Champlain was placed at 400 feet above the present sea level. New England and New Brunswick are regarded as having then formed a large island, separated from the mainland of New York by a strait, "which extended from the valley of the St Lawrence through the valley of Lake Champlain, of the Champlain canal and of the Hudson river. The summit level of the canal indicates the most shallow part of this strait which had a depth of about 125 feet."

Ebenezer Emmons[2] speaks of the "clays of Champlain and Albany" as marine and of the "connection by water of the Gulf of St Lawrence and the bay of New York." "New England and a part of New York were an island separated from the central part of New York by a narrow strait."

Mr Upham[3] in 1892 advanced the idea that at the close of the last glacial epoch the Hudson valley formed a glacial lake bounded on the north by the barrier of the ice sheet during the retreat from the basin of Lake Champlain and the St Lawrence valley. The barrier of this lake on the south was thought to have been due to an elevation of the present mouth of the Hudson which afterward sank beneath sea level. The subsidence of this coast is still going on, and the submerged channel of the Hudson has been mapped by the United States Coast and Geodetic Survey. The absence of marine fossils from the postglacial beds of the Hudson valley is taken as evidence that this valley has not been occupied by the sea either as an estuary or a strait at higher levels than the present since the ice age.

DeGeer[4] believed that the Catskill delta was formed at a time when New England and the contiguous portions of Canada were made an island by a strait on the west and the enlarged gulf on the north.

From a rapid review of several localities he constructed a chart of isobases of equal change of level. In the Hudson and Cham-

[1] Gray, Alonzo & Adams, C. B. Elements of Geology. N. Y. 1853. p.160–61.

[2] Manual of Geology. Phila. 1860. p.247–48.

[3] Bost. Soc. Nat. Hist. Proc. 1892. 25:335.

[4] Bost. Soc. Nat. Hist. Proc. 1892. 25:335.

plain valleys he placed the 0 isobase at New York and that of 600 feet elevation near Plattsburg.

Mr S. P. Baldwin in 1894[1] regarded the heavier sand deltas of the rivers tributary to Lake Champlain as the shore equivalent of the deep water clays with marine fossils and hence as marking the limit of salt-water invasion. In his opinion the sea did not reach higher than 150 feet at Whitehall and was 500 feet at St Albans in Vermont, giving a postglacial tilting of the land at the rate of 3 feet to the mile.

The higher beaches, 658 feet at St Albans as noted by De Geer, are described as slight and regarded as due to a glacial lake held in by the concave front of the retreating ice sheet. This lake it was believed penetrated into the Hudson valley through the Whitehall-Fort Ann valley.

[1] Pleistocene History of the Champlain Valley. Am. Geol. 1894. 13:170–84; map pl. 5, at p.170.

Chapter 11

COMPARISONS AND CONCLUSIONS

In the foregoing chapters the local history of the retreat of the ice through the Hudson and Champlain valleys has been presented in its general outlines, with its accompaniment of proglacial lakes of ever increasing length, finally giving way to the invasion of the sea over the Champlain district. It remains to compare certain phases of this history with reference to related data before proceeding to the drawing of such conclusions as appear tenable.

COMPARISON OF THE WATER LEVELS OF THE CHAMPLAIN AND HUDSON VALLEYS

The difference in the aspect of the surface deposits of the Champlain and lower Hudson districts is so great when viewed in the light of a critical diagnosis of glacial and marine phenomena that I am sure one coming from the easily recognized shore line and sea bottom phenomena of the Champlain valley to the mouth of the Hudson would find no equivalent indication of submergence in that district other than that which now appears to be in progress. All of the evidence in the lower Hudson appears to me permissive of a much higher stand of the land thereabouts during and since the retreat of the Wisconsin ice sheet began. But one serious point of difference which has been much discussed by Dr Merrill and myself concerns certain fine silty sands which occasion the tops of bluffs near the Hudson river, ranging in altitude up to 200 feet at least. It has seemed possible that some of this material may have been laid down over the district during a time of late submergence. In such places as I have examined the deposits or where they were examined in company with Dr Merrill, they seemed to me to be involved in the ice-laid drift in such a manner as to indicate their contemporaneity with the melting of the ice sheet in the southern Hudson valley and I have, rightly or wrongly, considered the evidence of the proglacial deltas and terraces with their ice contact borders and their exemption from overlying clays and marks of erosion by standing water as weighing more strongly in favor of the nonsubmergence of this

area since the hight and during the retreat of the Wisconsin ice sheet.

I have elsewhere commented on the difference in the inclination of the water levels in the lower Hudson and the Champlain valleys. The diagram, plate 28, has been prepared to spread before the eye some of the details bearing on this generalization. A particular explanation of the diagram will be found at page 254. In this graphic interpretation of the ancient water levels it will be seen that those of the lower Hudson are made to incline at about one half the angle of those over the Champlain valley. It would be a very hasty conclusion to infer without particular facts to support the view that this difference of rate of inclination is simply due to a more rapid rise of the land on the north. These evidences of water level cover a period as long as the entire retreat of the ice sheet, a time as yet of unknown duration but presumably measured by tens of thousands of years so that there has thus been time for many changes of level.

The terraces of the Hudson are too discontinuous and unrelated within short distances to draw very certain conclusions from their levels particularly in the district from the Highland canyon northward to the beginning of the Albany clay cover on the rock terraces. In the diagram, plate 28, I have compared the proglacial delta levels with the line A-B. This line accords well with the rise in level of these deposits toward the north till the vicinity of Newburg when great irregularity appears in terrace levels most of which bear the signs of deposition in the presence of the retreating ice tongue in the Hudson valley. Not only these latter but also those on the south which appear to decrease southward in elevation at a regular rate as indicated by the line A-B might plausibly be interpreted as made in a succession of water levels essentially parallel with the steeper inclined water planes over the Champlain district. In this view it is necessary to regard the entire eastern part of the State tilted to the north to such a degree that the line L–M on plate 28 is at sea level or parallel to sea level, and to regard the waters from the ice front at all stages of retreat as discharging through the Narrows in a some-

what regularly deepened channel excavated in the drift filling of the older rock gorge of the Hudson which it is to be presumed was quite as deeply filled when the ice began to retreat as it now is. The most serious objection which I have to this view is that it makes it necessary to suppose that the land remained at practically the same level throughout the epoch of retreat and till the beginning of the marine invasion on the north. If we accept, as on the whole seems necessary, the successive deltas rising to the north from near the Narrows to beyond the Highlands as indicating the actual water level within the valley during that portion of the ice retreat, then two alternative hypotheses present themselves to account for the difference of inclination of the earlier and later levels in the lower Hudson and Champlain valleys respectively. The first of these, the simple one, attempts to explain the difference of inclination by a more rapid rise on the north, not excluding, what the observed facts demonstrate, some depression on the south. Here again the fact that the attempt is made to compare the levels of water bodies which existed at very different times leaves the matter in doubt. The second of these hypotheses is that after the retreat had gone on with bodies of water standing in front of the ice with their levels approximately parallel owing to the stability of the land as regards tilting, the whole eastern part of the State became tilted down toward the north during the stage of Lake Vermont, and that in the subsequent reversal of this movement the same district participated blocklike in the change. There are no facts indicating precisely how far above sea level any part of the district lay, till the upper marine limit was established. For, though we may determine the rate of tilting by a change of the former sea level, it is obvious that the whole mass may have been undergoing a positive or negative movement at the same time that it was tilting.

The district shows a number of features which are better explained by this hypothesis than by the other view. In the first place, the Albany clays sheet the rock terraces of the middle and upper Hudson valley but are wanting over the Highland and southern section, their lithologic equivalents being there

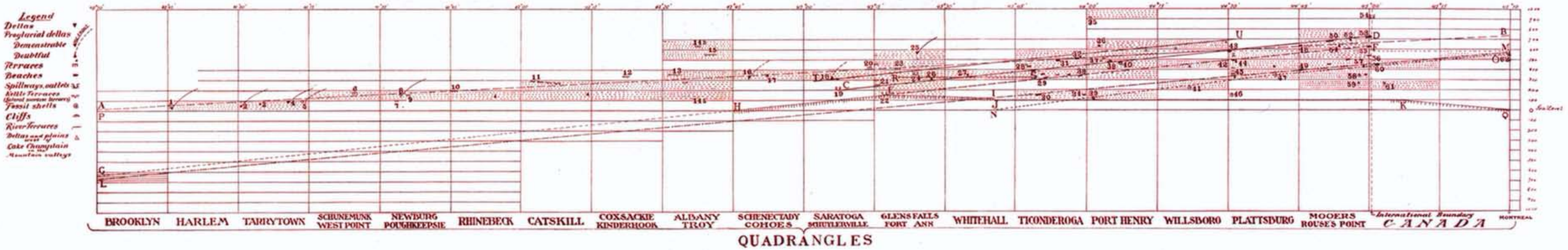
found in earlier proglacial clays. The water body in which the Albany clays were formed appears to have spread over the rock terraces and across the middle Hudson valley at a time when the region on the south rose above the water level, confining the waters to the excurrent stream lying within the gorge. The land must have been tilted to the north in comparison with its present attitude to have brought about such a distribution of effects. The well known phenomena of the submarine Hudson require also to be explained. While it is difficult to determine at what precise epoch the erosion phenomena there presented had their origin, the theory of high elevation on the south at this time is rendered permissive by the knowledge we have of the old channel.

DISTRIBUTION OF KETTLE HOLES MARGINAL TO THE HUDSON AND CHAMPLAIN VALLEYS

The accompanying plate [pl.28] represents the position and altitude of the kettle holes in the gravels and sands marginal to the Hudson river and the New York side of Lake Champlain. Some of these kettles, as on the Brooklyn sheet are in moraines, but most of them are in plains of gravel and sand marginal to masses of ice which lay at one stage or another in the valley. Excepting the type of kettle which occurs in the Brooklyn moraine, those northward along the Hudson and Champlain invariably represent the melting out of detached or buried blocks of ice from local deposits of gravel and sand which were at their time undoubtedly above sea level and presumably, on account of the barrier which the ice of their margin imposed, in an embarrassed drainage and hence above the level of standing waters farther along in the drainage system toward the sea on the south.

Such of these shallow depressions as came within the reach of the clay-bearing waters or later deposits of gravel and sand would have been buried. Thus it is strongly probable that the lower limit of kame kettles in the Hudson and Champlain valley lies at or above the upper limit of local submergence whether by long continued glacial lakes or the incursion of the sea. The lines representing on one hand the lower limit of kettles and on the other the upper limit of standing bodies of water should roughly corre-

PRELIMINARY PROFILE OF WATER-LEVELS FROM NEW YORK NARROWS TO MONTREAL



QUADRANGLES

spond. It is to be anticipated, however, that the kettle phenomena should be very irregularly spaced from north and south and more likely to be found in areas of frontal or strong marginal ice drainage than elsewhere.

Furthermore there may be more than one line of pitted plains and terraces at varying distances and elevations from the main drainage channel as has been explained in the preliminary account of glacial drainage.

The plotting of the known kettles gives an example in the moraine at Brooklyn at about 100 feet; some at the foot of Crow's Nest Mountain at 160 feet; and other shallow pits south of Poughkeepsie near Mine Point at about 170 feet, all of which fall fairly closely into a southward tilted plane, and all three lying above the water levels in that part of the Hudson river valley.

North of the above described kettles on the Rhinebeck sheet and the southern part of the Catskill sheet are small groups of high lying kettle deposits, probably marking earlier marginal deposits than those nearer the river when the Hudson river glacier had shrunk to smaller dimensions. The lowest of these depressions inclosed by the 240 foot contour near Elizaville overlooks a flat of water-laid deposits at about the upper limit of signs of standing water after the disappearance of the ice from this part of the valley.

On the whole the kettle holes on the Rhinebeck and the southern third of the Catskill sheet are above the general level, and those on the north and south are much above the levels marked by terraces or deltas indicating open, standing water.

Very few kettles obtrude themselves on our notice in going north to the southern part of the Troy and Albany sheets. Excepting one low kettle on the Troy sheet near Teller hill at 240 feet, the kettles from near Albany southward to the middle of the Catskill sheet fall along a tilted line which is about one half that of the tilt of the upper marine limit in the Champlain district. The actual tilt is at the rate of 2.8 feet a mile for about 50 miles.

Here again comes a decided break in the kame kettle deposits. From the northern middle portion of the Troy sheet to the northern part of the Schuylerville, there are none of these signs of deposition in the presence of ice near the Hudson river at levels

below 500 feet, but a number occur east of Troy between 500 and 720 feet, and one group on the Cohoes sheet at 600 feet. On the northern part of the Schuylerville sheet, kettle holes come in again at 360 feet near Moreau pond; and examples may be encountered along the rising profile line to the north on the Glens Falls sheet in the Glen lake district with inclosing contours at 420 feet, and still farther north on the Ticonderoga sheet at Street Road with inclosing contours at 540 feet. This line of kettle deposits rises northward at the rate of 3.2 feet a mile, or more steeply than the earlier ones on the south.

Comparing these three segments of lowest lines of kettle holes in the Hudson-Champlain trough, we observe that each going northward represents a successive later stage of the ice retreat, that each profile line on the north is successively more steeply tilted southward, and that these lines lie slightly oblique to a general line of tilted levels which may be drawn from the international boundary on the north to New York Narrows on the south.

It is reasonable to suppose that this increase in the tilt rate toward the north is not an original feature but depends on a change which has taken place in the attitude of the land, a change which is demonstrated as being a tilt in the same direction by an abundance of facts drawn from other kinds of evidence. It is furthermore probable therefore that each of these segments of kettles in tilted profile lines was more nearly horizonital originally than now and that the steepest of them was as flat as is now the least inclined. If this be true it follows that the degree of tilting increases northward from New York Narrows to Lake Champlain.

EVIDENCE FROM POTHOLES NEAR THE HUDSON GORGE

Glacial potholes, the so called giant kettles, are of value in determining the relation of land and sea when they occur in abandoned water ways or localities where glacial streams can be shown to have been the cause of their making. A number of localities of potholes have been described. A pair of these water-worn holes may be seen in the rocks at Wappinger Falls at an elevation of about 45 feet above sea level. Professor Osborn has described a glacial pothole near Catskill N. Y. N. L. Britton noticed large ones near Williamsbridge. O. P. Hubbard has described potholes opposite Catskill near the Hudson. Those on the

Mohawk above Cohoes have been measured and described by Mr Gilbert. Fitch mentions potholes on both sides of Wood creek in the gneiss and sandstone at various hights, one of them lying 60 feet above the canal. Some of these potholes are undoubtedly now in process of formation. No attempt has been made in this survey to determine the value of the known potholes in the eastern part of the State as indications of the relation to sea level during the time the ice was on the country. So far as those which have been described are concerned and are of glacial origin, they would apparently admit of the land being somewhat lower than it now is or indefinitely higher.

EVIDENCE OF HIGHER ELEVATION OF THE LAND IN THE SOUTHERN HUDSON VALLEY

Distinct evidence of a higher stand of the land in the middle and lower Hudson valley and over the submerged continental shelf is found in several kinds of facts.

The submarine valley already referred to as extending the Hudson seaward has often been appealed to as evidence of elevation during the glacial period. The channel probably means elevation at so late a time but no one has been able as yet to determine the precise epoch in the glacial period from any evidence the channel affords as to when the Hudson coursed through it. The existence of the channel is however permissive of elevation at any time during the Wisconsin epoch, and appears to the writer to be favorable to the view maintained in this paper.

Of the particular evidences found within the existing land area, the drowned Hudson gorge, the drowned mouths of its tributary streams, and the abundant evidence about the mouth of the river that the coast is now and has been sinking in relation to sea level are much better evidence of a higher stand of the land during the waning Wisconsin epoch than the submerged Hudson channel taken alone. Some of these more definitely timed indications of depression are described in the following notes.

In the southern Hudson valley the present is a time of relative depression following one of uplift of the land to a higher level than the present. That the land is undergoing or has recently undergone a change of level in the lower Hudson valley is shown by the character of many lateral stream valleys.

Thus the Croton river entering the Hudson on the east through a valley excavated before the Wisconsin epoch has a relatively broad mouth and is evidently engaged in silting up Croton bay, but previous to this existing stage and subsequent to the deposition of Croton point delta at that stage of the ice retreat there took place extensive alterations in the outline of that deposit through erosion along the present path of discharge of Croton river into Tappan sea. There is also the deep cut which divides Croton point delta into two parts now loosely tied together by beaches and swamps.

Cedar pond brook at Stony Point presents something of the same evidence. It has cut deeply through the North Haverstraw terrace which it built against the ice margin, as soon as the retreat of the glacier admitted of discharge into the gorge, but in its earlier excavatory work cleared away the bed below the present sea level, forming the back bay behind Grassy point which in the present stage has become partly filled with alluvium and swamp growth.

Peekskill cove might be cited as an analogous instance of depression in progress but there are reasons which have been set forth above for considering this as originally unfilled, the terraces being marginal to ice in the channel. The continuance of the cove as a small harbor, however, is dependent on the depression, for the streams which enter it are of considerable length and have no appreciable delta.

Popolopen creek on the south of the site of Fort Montgomery is another cove which seemingly should have been filled at least to the present water level were not the land now lower than it was at some epoch after the retreat of the ice sheet.

Likewise Fishkill creek enters the Hudson through an opening, now marsh filled, indicating considerable excavation below the present level of the sea before the actual water level was attained by the deposition of alluvium.

Wappinger creek, below the falls, is a drowned valley without a delta.

Rondout creek, coming in from the west and loaded with sediment, has evidently in recent times filled up a broader channel which demands considerable excavation below the present sea level at some epoch after the retreat of the ice.

Esopus creek, draining the southern field of the Albany clays, shows less signs of this change of level, and its delta is one of the marked recent alluviums of the Hudson river.

On the other hand Roeliff Jansen kill, which comes in from the southeast and enters the Hudson below Catskill from a region of clays and, higher up, sands, has a broad reentrant mouth, showing excavation at a preceding stage.

The Catskill is a large stream with a narrow gorgelike mouth in the clay terrace and possibly is not on its original path where it joins the Hudson.

Stockport creek is another broad creek valley now largely silted up but indicating broad erosion below the present sea level, subsequent to the deposition of the Albany clays.

From the mouth of Patroon's creek at Albany 42° 40′ north latitude, the relation of side streams to the Hudson gorge changes and above that point in the river the tributary streams have prolonged courses over the bed of the old channel. Lateral embayment of the mouths of these streams no longer takes place, and evidence of uplift or of excavation of the river bottom everywhere manifests itself in the rock floor of the ancient gorge by the behavior of the main stream and its tributaries.

If the northern Hudson valley is or has been rising and the southern part of the valley is or has been sinking, somewhere between the two areas must lie a line of no change of level. It has already been noted that a marked change in the character of the side streams in their relation to the gorge and its fiorded waters takes place at Albany which is near the head of tide. The actual delta of the Hudson river, as pointed out by Hayden[1] as early as 1820, occurs in this part of the river extending from near Albany southward probably as far as Coxsackie in the form of alluvial islands and shoals with ever increasing swampy mud flats.

It is presumable that the axis of rotation in the uplift of this region coincides with the present head of the delta or the vicinity of Albany, for, if this axis lay to the south of this point, marks of uplift in the side streams should appear farther south than they do and, if the axis lay to the northward at an appreciable distance, marks of depression in the mouths of side streams should manifest themselves instead of the signs of apparent uplift.

[1] H. H. Hayden in Geological Essays. Baltimore. 1820. p.35.

POSSIBLE OBJECTIONS TO THE ELEVATION THEORY

The view presented in this report that the land was for a part of the time during the retreat of the ice and at the time of the maximum submergence on the north several hundred feet higher than now at the mouth of the Hudson is, I am aware, in distinct opposition to the views held by some geologists and it seems necessary in this connection to meet the objections which may be raised so far as is permissible by the evidence now at hand. It should be borne in mind however that the time since the ice began to retreat is relatively long when compared with the time taken for such changes of level as are admitted by all in the St Lawrence district and that it may be that what at first is regarded as contradictory evidence of elevation and subsidence about the mouth of the Hudson river is but proof of movements which have succeeded each other.

Early in the field work on which this report is based it seemed to me probable that the land about New York city had not undergone since the ice began to retreat, a notable change of level either of uplift or depression and after examining the typical marine deposits and shore lines of the Champlain district it became evident that no recent marine deposit had been seen by myself or convincingly described by others above the most recent beaches in that southern field. I believe that one who has had the opportunity of studying attentively the Champlain marine district will be compelled to abandon the view of a postglacial submergence within the field of the Wisconsin drift sheet about New York city other than that now in progress.

The most positive statement which the elevation theory has to meet is the supposition of Professor Salisbury,[1] that the gravels of the Far Rockaway ridge on Long Island are a marine shallow water deposit of a date as late as the ice retreat, and the statement that they are regarded by him as the local equivalent of his Cape May formation in Southern New Jersey. From a reconnaissance of the area on Long Island I had about the same

[1] Salisbury, R. D. in Geologic Atlas of the United States, New York City Folio, no. 83. 1902. p.15, 16; *also* Surficial Geology Sheet of the Brooklyn Quadrangle, where the Far Rockaway deposit is given as "gravel and sand of marine shallow water origin."

time also referred the deposit to a nonglacial origin[1] but supposed it to be Prepleistocene because it was overlain about its base by the outwash plain of the Wisconsin moraines, and because I then saw no feldspathic pebbles which are so characteristic of glacially derived materials in this field. In revisiting the ridge with Messrs Fuller and Veatch in the spring of 1903, they pointed out a considerable percentage of compound gravels in the deposit allying it with the Pleistocene deposits, in referring it to which I fully concur with them. These authors regard the deposit as an outlier of the Manhasset,[2] a deposit of glacial origin containing much locally derived material and as I think all are agreed, deposited during a time of submergence. The deposit at Far Rockaway therefore has no bearing on the question of the attitude of the land during the late Wisconsin ice retreat; and if the Far Rockaway gravels and the Manhasset formation are the equivalent of the Cape May formation this last named with its signs of depression of the land in southern New Jersey must be contemporaneous not with the Wisconsin ice epoch but probably with the next preceding glacial advance or the Iowan.

It may be urged that if, at any time during the retreat of the ice, the land was raised several hundred (say 700) feet above sea level south of the Highlands, the Hudson gorge should there now be deeper, in the manner of the Norwegian fiord. In the absence of borings in the bed of the Hudson river we are in ignorance of the depth to bed rock in the deepest part of the buried channel. However deep the filling may be, undoubtedly a great amount of filling has been washed in from the clayey banks and the upper Hudson gorge which has been reexcavated in its clay filling. Since the deposition of the Albany clays something like 8 cubic miles of clay and coarser sediment have been removed from the old gorge between say Kingston and Fort Edward. If we suppose this sediment to have found its way to the bottom of the river between Peekskill and the Narrows, a distance of 65 miles, this supply of silt and clay alone would fill

[1] Woodworth, J. B. N. Y. State Mus. Bul. 48. 1901. p.651, also map pl. 1.

[2] Fuller, M. L. & Veatch, A. C. Results of the Resurvey of Long Island, New York. Science. 1903. 18:730.

a trench of that length 1 mile wide and 660 feet deep. Of course such an arithmetical calculation is solely intended to show that enough material has been transferred in the Hudson valley since the glacial period to more than fill to its present state an old gorge such as the elevation hypothesis supposes to have existed.

As we have no direct evidence that the Hudson gorge is so deeply excavated in the bed rock from West Point southward through the New York Narrows the question of altitude of the outlet at this particular stage under the conditions assumed must remain locally undetermined.

The width of the Narrows at the present sea level is approximately 1 mile and the banks are glacial materials. There is naught in the deposits at the Narrows to render a former deeper channel impossible. In fact, if we suppose the sides of the channel where it is narrowest to slope down at an angle no steeper than 30 degrees the slopes would meet at a depth of over 1500 feet below the present sea level, a depth much in excess of any required depth of the Hudson channel for the drainage of waters from the Hudson-Champlain valley under any of the conditions which are shown to have existed during the retreat of the ice sheet.

From a reference to the diagram plate 28, line G–H, it will be seen that the outlet of the Fort Edward stage of Lake Vermont at New York must now be submerged not less than 650 feet if the view taken on page 192 is correct.

DEFORMATION BY POSTGLACIAL FAULTS

From the vicinity of Greenbush northward into Argyle there is a belt of as yet unknown width in which the glaciated surfaces of nearly vertical slates are disrupted by small faults with a downthrow on the west, showing that in postglacial times the land on the western side of the Berkshire hills has come to stand relatively higher than that in the Hudson gorge and on the west of the river. Further detailed work in the field is required to make a quantitative statement concerning the amount of movement on these small faults. I have not been able without this detailed study to determine what role they may have played, if any, in

the tilting of the old water levels in the upper Hudson valley. The following note on the faults at Defreestville shows that these movements may assume some importance in the solution of the problem when their distribution has been accurately determined.

At Defreestville east of Albany a few rods from the road corners on the southeast road from that place there may be seen in the gutter well glaciated rock surfaces broken into small step faults each with a downthrow from a fraction of an inch to as much as 3 inches on the west. In a horizontal distance of 12 feet I measured a westerly downthrow of 1 foot vertical. It is probable that this zone of displacement has narrow limits but the local rate is as great as 440 feet change of level to 1 mile horizontal. The fact that the same small faultings occur on the bank of the river at Greenbush is indicative of a measurable change of local levels in the terrace of this part of the valley. No allowance has been made for these movements in the present report.

Mather[1] reported the existence of similar faults in slate rocks in Copake and Ancram. He mentions a locality near the end of Winchell's mountain and not far from the base of Mt Washington on the road from Copake to Boston Corners. He further cites Professor Merrick as having seen other examples, ½ mile west of Long pond in Clinton, in which the surface was displaced from 2 to 3 inches.

What appears to be a nearly north and south fracture with 3 or 4 feet throw with broken blocks of rock thrown into a narrow fissure occurs on the lake side of Trembleau mountain just south of Port Kent station. The downthrow in this instance is on the east in the direction of the lake valley. On Mt Monnoir near St Johns, Quebec, on the eastern side near the summit, similar evidences of fracturing appear with large inthrown blocks of rock from the sides. One of these cases was within the zone of wave action during the submergence; certainly that at Port Kent was within the zone of marine action. Wave action frequently opens small chasms in jointed and fractured rock but in a regressive movement of the sea it would hardly choke up such openings with large blocks from the sides in tumultuous disorder.

[1]Mather. Geol. N. Y. 1st Dist. 1843. p.156–57.

Chalmers describes small rock fractures of postglacial date in southern Quebec like those above mentioned near Albany, and the same kind of rock movement breaking glaciated surfaces has been reported in New Brunswick by G. F. Matthew.[1] It is evident that the changes of level which have taken place in this region have been accompanied by the local apparently widely distributed faulting of ancient rocks. It is hoped that special investigation of these dislocations in the upper Hudson valley will give data for applying a correction to the local data on which the recognition of the present attitude of the ancient water levels depend.

BEARING OF CHANGE OF LEVEL ON THE DURATION OF THE POSTGLACIAL INTERVAL

The elevation of shell-bearing beds at Montreal on Mt Royal to a hight of 550 feet together with the existence of the ancient marine limit marked by beaches at an altitude of 450 feet near the international boundary on the north slope of Covey hill, affords a basis for the calculation of the time which has elapsed since the marine shore lines were level water lines, provided the rate of tilting and local elevation can be satisfactorily determined. The fact shown in plate 28 and discussed in the preceding pages that an upper water level, apparently of lacustrine nature declines at a rather uniform rate from north to south in the Champlain region makes it evident that the assumption of any given rate of vertical movement e. g. 3 feet a century would be erroneous for all except one point in the elevated district. Far to the north of the international boundary in the Hudson Bay district, Bell has given his reason for thinking that elevation is now taking place at a rate between 4 and 5 feet a century. On the south along the coast at the mouth of the Hudson river, Cook and others have estimated that the coast is now being depressed in relation to sea level at the rate of 2 feet a century; but recent engineering measurements of tidal range show according to Mr George W. Tuttle[2] that at New York city since 1875 the subsidence has been at the rate of 1.45 feet a century. On the contrary from 1853

[1] Matthew, G. F. Post-glacial Faults at St John, New Brunswick. Am. Jour. Sci. ser. 3. 1894. 48:501–3.

[2] See bibliography, No. 148a.

to 1904 there appears to have been on the whole no permanent change of level. At the international boundary the rate must lie somewhere between 2 feet and 5 feet a century. On the Swedish coast elevation appears to be taking place at a rate of from 2 to 3 feet a century. Thus a rate of change of from 2 to 3 feet appears admissible for certain places on the earth's surface. Assuming that there has been constant uplift at Mt Royal, and that the rate has been that locally ascertained in the case of the Baltic coast and placing this at its maximum of 3 feet a century, it would have required 18,666 years to raise the highest shell bed on that mountain from sea level to its present hight above the sea. Again, if we assume that the rate of elevation has been faster at Mt Royal but not greater than 3 feet a century at the international boundary, where the upper limit of the Hochelagan marine invasion now stands at 450 feet, 15,000 years would be required to accomplish the result. This method of attacking the problem it will be seen is not likely to give definite results unless the actual rate of vertical movement at the point where the elevation of the ancient water level is taken be known. In this district the data have not been gathered.

Thanks to Mr Gilbert's studies of the changes of level now taking place in the Great Lake basins the assumption may be made that on one of the radial lines of the apparently dome-shaped uplift which has taken place in this northeastern part of the country the rate of tilting on a south-southwest direction is such as to displace the two ends of a line 100 miles long .42 of a foot in 100 years. The line of water level traceable through Lake Champlain and southward through the Hudson exhibits a displacement showing uplift on the north and depression on the south such as to make the assumption of a southward tilting in this direction at a rate comparable to that made out for the Great Lakes. Making this assumption with the additional postulate that the present rate has held during the past, the following data lead to the conclusion stated below.

At Covey hill on the international boundary the marine limit is 450 feet. Twenty-six miles north a littoral deposit of shells occurs on Mt Royal at the hight of 550 feet. The difference of level today between these two stations is at least 100 feet.

Originally the two localities were at the same sea level. If the tilting took place at the rate of .42 of a foot in 100 miles, in 26 miles it would take place at the rate of .1092 feet in 100 years, and as the Montreal station is 100 feet above that at Covey hill we obtain the ratios (neglecting the third and fourth decimals): as .1 foot is to 100 years, so is 100 feet to the time required to elevate the Mt Royal station 100 feet above the Covey hill station. Solving this simple proportion we obtain 100,000 years as the time required. At this rate the land must have risen at the rate of .55 feet ($6\frac{6}{10}$ inches) a century at Montreal and .45 feet ($5\frac{4}{10}$ inches) a century at the international boundary on the north and south line passing through the Champlain and Hudson valleys.

This estimate of 100,000 years is for the time since the highest marine beach was level. This highest beach marks approximately the time of disappearance of the ice sheet from the St Lawrence valley so as to permit the free incursion of the sea. If the assumption used in this calculation were right it would follow that the Laurentide ice sheet disappeared from the St Lawrence valley as long as 100,000 years ago.

It may be, though, that the rate of tilting in the northsouth direction through the Champlain-Hudson valleys is now and has been at a more rapid rate than that ascertained for the Great Lake district on a south-southwest line. If we assume the rise at Montreal has been at a rate five times as fast as that inferred above or 2.75 feet a century then it has required 20,000 years to effect the change. It does not seem possible that the rate of uplift at Mt Royal could have been on the average more rapid than 2.75 feet in 100 years and there is no reason to assume that it was slower than the rate of tilting now observable in the Great Lakes district. The disappearance of the ice sheet from the low grounds about the northern open mouth of the Lake Champlain valley may be said therefore with some probability to have taken place not less than 20,000 years ago and not longer than 100,000 years ago. That it was somewhere between these limits is more probable than that it was either 20,000 years or else 100,000 years ago.

There is yet another method which though equally interesting is not more trustworthy perhaps. By reference to the diagram, plate 28, it will be noted that on the assumption of essential

rigidity in the movement of the crust from New York to Montreal, when the sea was at the upper marine limit in the Champlain country the site of New York city must have been about 650 feet above sea level. If now the rate of depression which has brought about the change of level at New York postulated by this view be assumed to have been in the long run 2 feet a century, it will have taken 32,500 years to accomplish the change which has occurred since the sea stood at its upper limit in the St Lawrence valley. Such figures mean only that the postglacial epoch or phase for the glaciated portion of the country is to be measured, as Gilbert has stated it, by tens of thousands of years.

COMPARISON OF NORTHERN AND SOUTHERN MOUTHS OF THE HUDSON-CHAMPLAIN DEPRESSION

The most striking differences are apparent in the recent geologic history of the lower Hudson valley and the wide open mouth of the Champlain valley. In the northern area there are abundant beaches of strong development attesting the action of powerful waves with a fetch of wind over wide sheets of water, and certainly the lower of these water levels are marine as abundant marine fossils in sands and clays from an altitude of 350 feet down to the level of Lake Champlain testify. The typical glacial topography over the plains below the marine limit is largely smothered by wave action involving cutting and filling. Where moraines or eskers exist, they are incised by the horizontal lines of wave action. More than all this the existence of a broad estuary is attested by the widespread distribution of clays bordering Lake Champlain, clays on which in the central areas remote from the old shore lines and sand deltas no newer deposits repose.

In the southern area including the vicinity of New York city and the wide valley of the Passaic and Hackensack, a relatively low area analogous to that at the northern end of Lake Champlain, recognizable wave lines have not been found, no undoubted marine beach, bar, or cliff is known to exist above the present sea level. The glacial deposits are, except in marshy and swamp areas at the surface without suffusion by clays which ought to be expected if the region had been submerged for any appreciable length of time. A diligent search conducted for certainly over

half a century by numerous observers whether amateurs or official geologic surveyors has failed to bring to light *postglacial* marine fossils above the level of the sea at the mouth of the Hudson.

The comparison of the extreme ends of the great Hudson-Champlain depression speaks eloquently of marine submergence on the north during a time when the region on the south about the mouth of the Hudson at least was as it now is above the level of the sea.

SUMMARY OF GEOLOGIC HISTORY BEGINNING WITH THE RETREAT OF THE WISCONSIN ICE SHEET

From the foregoing more or less detailed but as yet incomplete account of the successive frontal moraines in the Hudson and Champlain valleys, it follows that the ice front after receding from the moraine at New York Narrows became more and more irregular in outline, more and more reduced to a long loop projecting southward in the Hudson valley and receding northward over the highlands which formed a wall on either side of it. When the ice had so far dwindled away as not to be able to surmount the Archean ridge of the Highlands, it still pushed southward through the Hudson canyon in this elevated district a narrow tongue of ice which has left its marginal deposits of stratified gravel, sand and clay, at Croton Point, North Haverstraw, about Peekskill, and in the vicinity of West Point. During this stage of the waning Wisconsin epoch, the land from the Highlands southward through the lower Hudson valley appears to have been occupied by standing water about the margin of the receding ice. The level of this body of water is now marked by proglacial deltas which rise to the north at the rate of about 2.6 feet a mile;[1] an inclination very close to that found by Kümmel for the shore lines of Lake Passaic in New Jersey.

When the ice disappeared from the Wallkill valley about the northern slopes of the Highlands, it formed a long tongue from Newburg northward covering the greater part of the width of the floor of the Hudson valley. About its margins were accumulated stratified gravels and sands now in the form of terraces, with kettles and ice-block holes, extending on its eastern margin north-

[1]This estimate is obtained by taking the distance, 34.5 miles, from the College Point delta with an elevation of 30 feet, to the terrace used for a state military camp at Peekskill with an elevation of 120 feet.

but south of this latter named point there is no trace of deposits so late as this stage in the glacial retreat now recognizable above the summit line of the walls of the Hudson gorge. It is to be inferred therefore that Lake Albany had its southern limit somewhere in the vicinity of Rhinebeck and Rondout and that south of that point the surface of the rock terraces were then and have ever since been above the level of standing water.

The shore lines of Lake Albany, determined by the hight of marginal deltas, now rise to the north at a somewhat steeper rate then the land on the south of the Highlands, but from Newburg northward for several miles there is great discrepancy in the level of deltas marginal to the gorge, some of the terraced deposits being of a character and elevation to suggest that the water level varied greatly from time to time. On the whole the deltas from Rondout northward to Albany appear to lie in a tilted plane which, if continued southward, passes below that in which the deltas from the Highlands southward lie. This is interpreted to mean that, as time went on, the detritus in the lower Hudson gorge and about its mouth, in and about the terminal moraine, was swept away by powerful currents lowering the level of the waters about the ice margin. This of course could only take place if the land were far enough above sea level to render the water levels in the Hudson valley independent of the control which would be exerted by a submergence in the sea. The facts seem to indicate that the land was so far tilted down on the north and up on the south that Lake Albany, held in by the ice front on the north, was caused to spread over the rock terraces in the upper Hudson valley while an outlet for its waters was found through the gorge on the south of Rhinebeck below that at which the sea stands today.

For a time the waters of Lake Albany extended northward over the Fort Edward district, covering the lower portion of the plateau about Fort Ann; and thence, connecting through the narrow defile of Wood creek, united with a glacial lake which was extending northward in the valley of Lake Champlain pari passu with the retreat of the ice from that valley. The attitude of the land from Lake Champlain southward to the region of Lake Albany was now that of depression on the north so that the floor of Lake

Champlain was below sea level though the sea was as yet excluded by the ice. The region about Fort Edward was above sea level as will be noted from the next feature in the sequence of events.

From some cause which can only be at present postulated from the known conditions of the time and hence probably the effect of the powerful discharge of the drainage through the Hudson gorge, coming not only from the melting ice in the Champlain district but as well as from the intake from Lake Iroquois which was now in existence on the west of the Adirondacks, the waters of Lake Albany were drained off. That this withdrawal was due to a deepening of the Hudson gorge on the south rather than to a change in the attitude of the land is indicated by the fact that the shore lines of the Champlain district show no signs of a disturbance at this time. With the withdrawal of the waters over the Albany district, a divide partly of glacial materials and partly of the bed rock was revealed between the nascent glacial lake over the Fort Edward basin and in Lake Champlain valley and the region on the south, and waters began to spill over this barrier west and south of Schuylerville across those fields which were later the scene of Burgoyne's defeat. Thus Lake Vermont was born, consisting, on the south of the mountainous ridges between two of which Lake George lies, of a shallow lake over the Fort Edward district, and a constantly enlarging body of water on the north, Lake Vermont proper.

The discharge at this spillway is believed soon to have cleared out and shifted into an older channel which forms a now partly abandoned river valley just west of Schuylerville. The stream at this stage entered the Hudson gorge at Coveville with a fall over the Hudson slates at that point. At this time the Hudson gorge proper from Coveville northward to Northumberland must still have been filled with glacial gravels and the clays which may still be seen on the valley sides.

Thus was formed the Coveville stage of Lake Vermont. The water level was now about 100 feet lower than in the previous initial stage, and if the correlation worked out in this report is correct, the lake was at this time about 200 feet above the then sea level. The floor of the Hudson gorge at Coveville was

about 100 feet above sea level as it is today. The Hudson gorge from Coveville southward must have been largely cleared of the clays and other glacial deposits.

Gradually the filling of clays in the old gorge through which the Hudson now passes Schuylerville was removed and the discharge from Lake Vermont fell into this lower channel reducing the level of the waters on the north till they fell to the level of the present divide between the Hudson and Champlain drainage in the Wood creek valley just northeast of Fort Edward, where the lowest point in the hight of land between the St Lawrence and the Hudson valley is only 147 feet above the sea. This stage of Lake Vermont, when all traces of a lake had disappeared about the Fort Edward district, found the Hudson from Fort Edward southward a much more powerful river than it is now.

During the development of Lake Vermont and as soon as the ice had withdrawn from the northern slope of the Adirondacks to the very border of that district, a powerful discharge of water coursed along the ice front from the St Lawrence valley to the eastward and fell into the lake near West Chazy. The course of this torrent is marked by the so called "flat rock" areas from Covey hill southward through Altona. Somewhat later, when discharge at a lower level was permissible, the waters excavated a gorge with a fall at its head on the south side of Covey hill. The Gulf with its lakelets stands as a silent monument of this vanished river.

At a yet later stage, following the stand of the waters in Lake Vermont under the control of the Fort Edward outlet, the ice barrier on the north began to give way; the waters leaked out northward, we are at liberty to suppose, thus lowering the lake level step by step; and then when the ice was no longer a barrier the sea came in at a lower level, the position of which seems to be determined, from a study of the upper limit of beaches on Covey hill, and by the upper limit of shells and the related data in the Champlain valley. As pointed out in the text, the sea appears not to have extended farther south than Whitehall at which time the land on the south was as high if not higher than now.

Subsequent to the invasion by the sea, the land began to rise on the north and to sink on the south, a movement which is, according to the evidence obtained by Gilbert and others in the Great Lake district, and by Cook and others along the coast east and south of New York, still going on. In the valley of Lake Champlain we find the indisputable evidence of uplift as high as marine shells occur. About the mouth of the Hudson we observe evidences of recent sinking and though we can not, from what we see there, determine how long the depression has been going on, it would seem as if the land must have gone as far beneath the sea at that end of our line of ancient water levels as it has risen out of the sea on the far north.

POSTSCRIPT

If the sections of the Hudson river bed near New York city presented by Professor Hobbs[1] in a recent paper include borings to bed rock rather than boulders, it would appear for the first time that the Hudson gorge at the latitude of New York city is not more than perhaps 350 feet deep beneath sea level; but the evidence is as yet by no means conclusive on this point.

[1] Hobbs, W. H. Origin of the Channels surrounding Manhattan Island, New York. Geol. Soc. Am. Bul. 1905. 16:151–82. *See* fig. 22–24 and p.176–79.

APPENDIX

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EXPLANATION OF PLATE 28

This plate is a north-south profile, in which the vertical lines represent the latitude lines, 15 minutes apart, which form the north and south boundaries of the quadrangles or sheets of the state topographic map. The horizontal and inclined lines represent existing and ancient water levels with their angle of tilt in the double scale of the section. One inch vertical equals 533 feet; one inch horizontal equals about 13.3 miles. The legend attached to the sections explains special symbols. The several lines, A-B, etc., indicate the following:

A-B The solid part of the line connects the highest beach found at Port Kent (Plattsburg quadrangle) with the highest beach at Street Road (Ticonderoga sheet) and represents the present tilted attitude of this old water level between the two localities. The dotted extensions of the line north and south meet certain beaches on the north and come near the level of the deltas made in front of the retreating ice sheet in the Highlands and southward; it is a line of comparison. So far as present evidence goes the waters of glacial Lake Albany and Lake Vermont did not rise above the line. The deposits found above the line appear to have been made in local bodies of water marginal to the ice sheet or to have been deposited by glacial streams confined on rock terraces similarly to those at West Point. Further investigation may show that some of the shore line traces along this line on the north and certain deltas in the middle Hudson valley were made at different times in different water bodies.

C-D Lake Vermont, with beaches and deltas, at the time of discharge through the Coveville channel or spillway below Schuylerville. It will be noted that this water level crosses the line A-B at the southern border of the Plattsburg quadrangle near Port Kent. If A-B really coincides with the earlier water level of the Champlain valley, it follows that the land was tilted down toward

the north after the waters abandoned the A-B level and before C-D was formed, causing the waters on the north of Port Kent to submerge the old level.

E-F Lake Vermont at the next lower stage after the opening of the old gorge through which the Hudson now flows at Schuylerville, and when the outlet of the lake was in the Wood creek channel near Dunham basin above Fort Edward, the present divide between the Hudson and Champlain drainage.

G-H Represents the extension of the present inclination of the bed of the Hudson gorge from the divide at E southward to the head of tide where the rock floor disappears. If the above water levels are correctly measured, it is necessary to suppose that the rock floor of the Hudson is at least as deep at any particular point in the Hudson valley as the line G-H indicates for that point, and since the bed of the rock gorge must have deepened toward the mouth on the south the real depth of the gorge is presumably deeper than is indicated by the line G-H.

H-E-I Indicates the profile of the bed of the rock channel from near Mechanicville to Whitehall at the head of Lake Champlain.

J-K The approximate level of Lake Champlain, 98 feet above sea level.

L-M The inclination of the upper marine limit. Note that since E-F was level the land has risen more at the international boundary than at Whitehall for E-F and L-M are not parallel. M is at Mt Royal back of Montreal, Canada.

N-O A line passing through the highest shell localities from Montreal (550 feet) along the western side of Lake Champlain to near the head of the lake. A straight line passing through the two highest shell localities would meet the surface of Lake Champlain near Whitehall.

P-Q Present sea level.

R-S The level of Lake George.

The numerals indicate the following localities, a description of which will usually be found at the page indicated:

1 College Point delta, Harlem sheet [p. 90]
2 Tappan moraine and outwash plain [p. 93, pl. 2]; Tarrytown sheet
3 Tarrytown delta, Gory brook; Tarrytown sheet [p. 96]
4 Ice front at Croton point; Tarrytown sheet [p. 98]
5 North Haverstraw frontal terrace; Tarrytown sheet [p. 100]
6 West Point and Cold Spring terraces; West Point sheet [p. 111]
7 Roseton terrace; west bank of Hudson; Poughkeepsie sheet [p. 119]
8 New Hamburg lateral moraine terrace, mouth of Wappinger creek; Poughkeepsie sheet [p. 119, pl. 5]
9 Marlboro lateral moraine terrace; west bank of Hudson [pl. 5]
10 Lateral moraine terrace south of Hyde Park; Rhinebeck sheet [pl. 6]
11 Lateral moraine kettle terraces from Cokerville northeastward through Livingston; east side of Hudson; Catskill sheet [p. 121, pl. 7]
12 Lateral moraine terrace kettles 2 miles northwest of West Coxsackie; west side of Hudson [not further described]
13 Schodack terrace; Troy sheet [p. 122, pl. 8]
14*a* Kenwood terrace, a faint river terrace west bank of Hudson near Kenwood; Albany sheet [p. 199]
14*b* Kame terrace southeast of West Sandlake [p. 126]; Troy sheet
15 Cooper pond kame terraces; Troy sheet [p. 227]
16 Supposed ice front north side of Mohawk delta near Schenectady; Schenectady sheet [p. 131]
17 Hoosic delta; Cohoes sheet [p. 134, pl. 10]
18 Delta of the Batten kill, south of the stream. The delta symbol on right and lower down stands for the delta plain north of the river [p. 137, pl. 11]
19 Old outlet of Lake Vermont; symbol placed at Grangerville; Schuylerville sheet [p. 196, pl. 11]
20 Glacial terrace at Moreau pond [pl. 12]; Schuylerville sheet

21 400 foot terrace delta of Adirondack-Hudson; east base of Palmertown mountain; 350-60 foot terrace farther east; Glens Falls sheet [p. 145, pl. 13]

22 Outlet of Lake Vermont, Fort Edward stage; in channel near Dunham basin; Glens Falls sheet [p. 198, pl. 13]

23 Terrace plain southwest of Glen lake about 1 mile southwest of Rush pond; Glens Falls sheet [pl. 13]

24 349 foot outlet (?) south of Lake George east side of French mountain; Glens Falls sheet

25 Outwash plain from ice at southern end of Lake George, north of Bloody pond; Glens Falls sheet

26 Delta of the Mettawee river; West Granville; Fort Ann sheet [p. 149]

27 Delta of the Poultney river, Fairhaven Vt.; Whitehall sheet [p. 150]

28 Probable beach lines east base of Cooks mountain; Ticonderoga sheet

29 Boulder pavement north base of Cooks mountain, south of Trout brook; Ticonderoga sheet

30 Shore line of flat east of old Fort Ticonderoga; Ticonderoga sheet

31 Upper beach line on glacial terrace, Sawyers hill, north of Street Road; Ticonderoga sheet [p. 155, pl. 15]

32 Stony beach line 1.5 miles northwest of Crown Point Center; Ticonderoga sheet [pl. 15]

33 Surface of terrace 2 miles northwest from Crown Point; Ticonderoga sheet [pl. 15]

34 Wave-cut lines on shoal 1.5 miles northwest from Burdicks crossing; Ticonderoga sheet [pl. 15]

35 Gravel terrace on Grove brook, southwest of Port Henry; Port Henry sheet [pl. 16]

36 Fragment of delta south side of Mill brook, back of Port Henry; Port Henry sheet [pl. 16]

37 Probable shore lines back of Port Henry [pl. 16]

38 Faint beach at base of rock cliff north of Port Henry and east side of abandoned mines and village [pl. 16]; Port Henry sheet

39 Fossil shells on Crown Point peninsula [p. 213]

40 Wave-cut (?) terrace levels on delta of Mullen brook [pl. 16]; Port Henry sheet

41 Fossil shells near Willsboro; Willsboro sheet [p. 213]

42 Wave-heaped ridge back of Port Douglas; Willsboro sheet

43 Spitlike deposit of coarse debris north side of Trembleau mountain, back of Port Kent; Plattsburg sheet [pl. 21]

44 Dissected delta of Ausable at Keeseville, and shore lines; Plattsburg sheet [pl. 21]

45 Sea cliff cut in till near old tollgate, back of Port Kent; shore lines in till above cliff; also approximate surface of a delta plain of the Ausable [p. 204, pl. 21]

46 Fossil shells near Port Kent railroad station [p. 212, pl. 21]

47 Fossil shells; Freydensburg's mills on the Saranac; Plattsburg sheet [p. 211]

48 Faint beach south by west from Beekmantown, southern edge of Mooers sheet [pl. 29]

49 Beach ridge or broad bar in Beekmantown, south of Silver Creek; Mooers sheet [pl. 29]

50 Cobblestone hill, wave-washed moraine; about 3 miles northwest from West Chazy; Mooers sheet [p. 172, pl. 29]

51 Altona delta; at Altona; Mooers quadrangle [p. 172, pl. 29]

52 Dissected delta on the north branch of the Big Chazy river south of Deer pond in Mooers; Mooers sheet [pl. 29]

53 Cobblestone beach ridges with hooks; at head of Kellas brook; Armstrong's Bush, northwest corner of Mooers sheet [p. 172, pl. 29]

54 Spillway at the Gulf, head of upper lakelet, south of Covey hill, partly in Canada [p. 161, pl. 25]

55 Faint beach flat on Kellas brook, Armstrong's Bush, northwest corner Mooers sheet [p. 172, pl. 29]

56 Highest of the series of beaches between 538 and 360 feet along the international boundary west of west branch of English river [p. 173, pl. 29]

57 Delta of the English river [pl. 29]

58 Fossil shells; Big Chazy river, 1 mile above Thorn; Mooers quadrangle [p. 210]

59 Delta of the Big Chazy river at Mooers; Mooers sheet [pl. 29]

60 Upper marine limit on the north slope of Covey hill, Canada, between Vicars and Franklin [p. 173, pl. 25]

61 Fossil shells south of Hemmingford, Quebec [p. 210]

62 Fossil shells at Côte des Neiges, on Mt Royal, Montreal, Quebec [p. 209]

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New York State Museum

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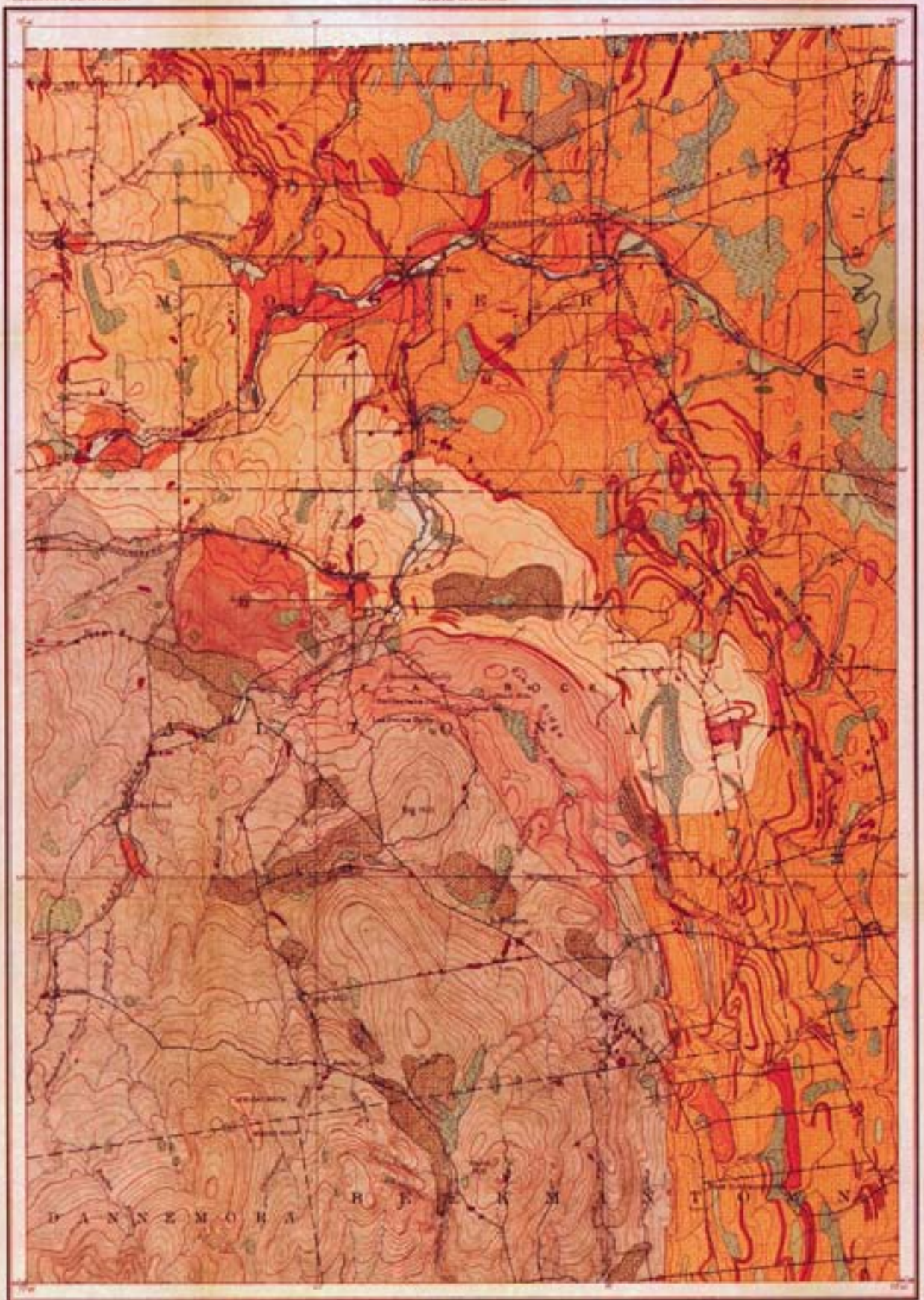
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BASE by U. S. GEOLOGICAL SURVEY

Panoramic Geology by J. B. Woodworth

New York State Museum

The New York State Museum as at present organized is the outgrowth of the Natural History Survey of the State commenced in 1836. This was established at the expressed wish of the people to have some definite and positive knowledge of the mineral resources and of the vegetable and animal forms of the State. This wish was stated in memorials presented to the Legislature in 1834 by the Albany Institute and in 1835 by the American Institute of New York city and as a result of these and other influences the Legislature of 1835 passed a resolution requesting the secretary of state to report to that body a plan for "a complete geological survey of the State, which shall furnish a scientific and perfect account of its rocks, soils and materials and of their localities; a list of its mineralogical, botanical and zoological productions and provide for procuring and preserving specimens of the same; etc."

Pursuant to this request, Hon. John A. Dix, then secretary of state, presented to the Legislature of 1836 a report proposing a plan for a complete geologic, botanic and zoologic survey of the State. This report was adopted by the Legislature then in session and the governor was authorized to employ competent persons to carry out the plan which was at once put into effect.

The scientific staff of the Natural History Survey of 1836 consisted of John Torrey, botanist; James E. DeKay, zoologist; Lewis C. Beck, mineralogist; W. W. Mather, Ebenezer Emmons, Lardner Vanuxem and Timothy A. Conrad, geologists. In 1837 Professor Conrad was made paleontologist and James Hall, who had been an assistant to Professor Emmons, was appointed geologist to succeed Professor Vanuxem, who took Professor Conrad's place.

The heads of the several departments reported annually to the governor the results of their investigations, and these constituted the annual octavo reports which were published from 1837 to 1841. The final reports were published in quarto form, beginning at the close of the field work in 1841, and 3000 sets have been distributed, comprising four volumes of geology, one of mineralogy, two of botany, five of zoology, five of agriculture, and eight of paleontology.